SCHOOL OF CIVIL ENGINEERING

INDIANA DEPARTMENT OF HIGHWAYS

JOINT HIGHWAY RESEARCH PROJECT

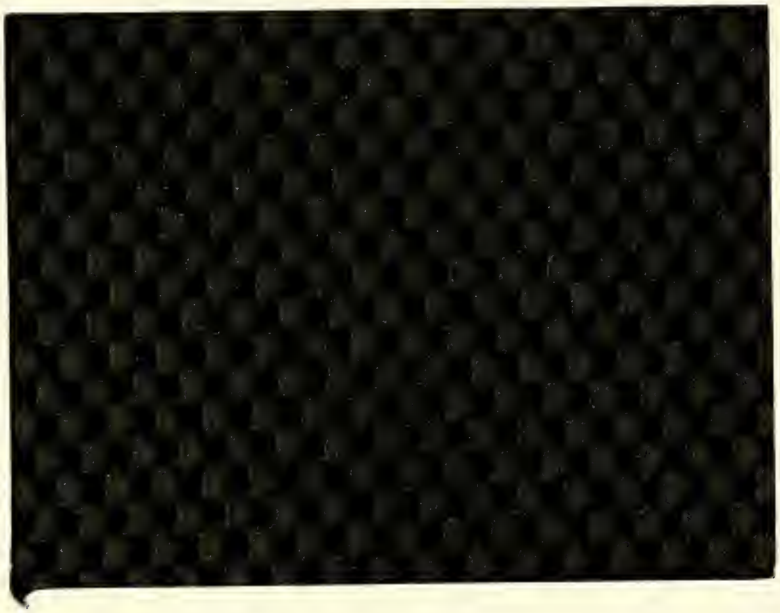
JHRP-87/12

Informational Report

PLACEMENT RATES FOR HIGHWAY EMBANKMENTS WITH VERTICAL AND HORIZONTAL DRAINAGE

A.G. Altschaeffl
S. Thevanayagam

PURDUE UNIVERSITY



JOINT HIGHWAY RESEARCH PROJECT

JHRP-87/12

Informational Report

PLACEMENT RATES FOR HIGHWAY EMBANKMENTS WITH VERTICAL AND HORIZONTAL DRAINAGE

A.G. Altschaeffl
S. Thevanayagam

Informational

Report on

Placement Rates for Highway Embankments with Vertical and Horizontal Drainage

Prepared for

State of Indiana, Department of Highways

By

A. G. Altschaeffl
S. Thevanayagam

March 1987

TABLE OF CONTENTS

1. Introduction

"Modified Sand" is a computer program for the general analysis of an embankment foundation on a soft soil with consideration of vertical and horizontal consolidation without any sand drain installations. This is a modified version of the program SAND (Krizek and Krugmann, 1972) that can be used to analyze this problem with consideration of vertical sand drains. The solution technique in the modified program remains the same as in the original program.

1.1 Capabilities of Modified Sand

This program optimizes the rate at which a specific highway embankment can be constructed on soft soil. This problem involves the computation of stresses and pore pressures in the subsoil, the dissipation of these pore pressures, the corresponding increase in shear resistance and stability of the embankment.

The embankment load which is assumed to act vertically, induces pore pressures in the subsoil which are computed using Theory of Elasticity and Skempton's pore pressure parameters (A, B). These pore pressures dissipate according to three dimensional consolidation theory which takes into account the effect of gas and variable soil parameters. The solution of consolidation equations are solved numerically by treating it as an eigenvalue problem. As the pore water pressure dissipates the effective stresses in the subsoil will increase giving a simultaneous

increase in shearing resistance. Settlements are computed from the dissipated pore pressures.

There are two options available.

<u>Option 1</u>: (For ISP = 0) -- The program determines the times at which each lift whose resulting shapes are input can be constructed without exceeding the bearing capacity of the subsoil and after a specified fraction of a reference settlement has occurred. Settlements and average degree of consolidation are output for specified points in a graphical form.

<u>Option 2</u>: (ISP = 1) -- The lifts and times of lift application are input and the program determines the dissipation of pore pressures and settlements for specified points. Bearing capacity of the foundation soil is not analyzed.

2. Description of the Program

Described in the subsequent sections is the set of computer programs which can be used to analyze an embankment foundation on a soft soil with consideration of vertical and horizontal consolidation. Individual routines, consisting of main program "Modified Sand" are written in FORTRAN 77. Program listing is attached in Appendix A. The programs have been tested in IBM PC XT and VAX 11/780 at Purdue University.

Each subsection of the program is given below explaining the following:

1. Purpose of the program.

2. Usage of the program.

3. Block names.

4. Description of parameters.

5. Method of solution or calculation.

6. Subroutines required.

In addition a list of sequence of input of data into the main program is given.

Two sample problems which illustrate most of the special features of the programs and solutions to these problems are attached.

2.1 The Main Program Modified SAND

Purpose of the Programs:

SAND -- To analyze an embankment foundation on a soft soil for stability and/or settlements and consolidation behavior with consideration of horizontal and vertical drainage.

Block Names and Lengths:

```
SAPOD/ IOUTP,W,HH,GLOAD,CLOAD,NARC,NRAD; length:  7 words
SADI1/ LAYER,IBCV,MHE,M,N,IDC,NDR,ISUM; XET(41); length:  49 words
SADI2/ FIMPV,RC,RK,C,RO,RE,TA,ISP,IVAR; length:  29 words
SACSE/ ROC,ROCL,SVM,P,PC,PLOG,PO,PCO,IAV,IK,ISAT,AAV,AAH; length:
                                                          54 words
```

SACO1/ AVOC,KVO,KHO,EOPUS,PU,SKHM,SKVM,CCC,NNN,ICOEF; length: 10 words

SACO2/ PCV(10),CVIN(10),PCH(10),CHIN(10),ICV,KOUNT,HF; length: 43 words

SADET/ XSTAB(51),YSTAB(11),DX,DY,YWM,TGPHI; length: 66 words

These blocks are only defined in program SAND

SAPOD is needed in subroutines DETFS,DISP,INIT,PORE, and VARYR
SADI1 and SADI2 are needed in subroutine DISP
SACSE is needed in subroutines COEF and SETL
SACO1 and SACO2 are needed in subroutine COEF
SADET is needed in subroutine DETFS

Description of Parameters

On the following pages are described the parameters which are input by the user; quantities listed in labelled COMMON blocks are given in the respective subroutines. This list is given in alphabetical order. Section (3) provides the list where data cards of the parameters appear in the sequence in which they are needed in the programs. The asterisk * refers to a note at the end of the list.

A - Skempton's pore pressure coefficient

AVO - constant coefficient of compressibility to be used in the settlement computations; in the case of two layers, AVO applies to the upper layer; dimension; ft/lb

AX(I) - subinterval limits to be input as decimal fractions of reference value W; I=1,NI where NI < 5

B - Skempton's pore pressure coefficient

BLANK - symbol to be used in the resulting plots

C - fraction of the reference load at time TA, which is applied at time equal to zero; may vary between 0.0 and 1.0

CC - compression index; negative slope of the void ratio versus effective stress curve (virgin part of the curve); in the case of two layers, CC is the compression index of the upper layer

CLOAD - undrained strength of the embankment oil dimension - psf

CO(I) - initial undrained strength of the subsoil; I=1, NC where NC ≤ MYE ≤ 11. If NC < MYE, Lagrangean interpolation is used to compute the undrained strengths at MYE equally spaced depths. If NC=MYE, the input values must be provided at equally spaced points where I=1 and I=MYE coincide with the surface and the bottom of the compressible layer, respectively; dimension - psf

COUNT* - marker to indicate the last residual pore water pressure data card; this parameter is zero on all residual pore water pressure data cards, except on the last card, where it must take value different from zero

CP(I) - ($c/\overline{p}$)-ratios of the subsoil; I=1, NC; see remarks under CO(I)

CH - constant coefficient of consolidation in horizontal direction; in case of two layers, CH applies to the upper layer; dimension - ft^2/day

CHIN(I) - variable coefficients of consolidation in horizontal direction; I=1,ICV ≤ 10; stress-dependent coefficients of consolidation in horizontal direction are obtained within subroutine COEF by interpolation between the CHIN-values; dimension - ft^2/day

CV	- constant coefficient of consolidation in the vertical direction; in case of two layers, CV applies to the upper layer; dimension - ft^2/day
CVIN(I)	- variable coefficients of consolidation in the vertical direction; I=1, ICV ≤ 10; stress-dependent coefficients of consolidation in the vertical direction are obtained within subroutine COEF by interpolation between the CVIN-values; dimension - ft^2/day
DMAX	- maximum step size to be used in the variation of XC and YC in the search procedure for the minimum factor of safety; dimension - feet
DMIN	- minimum step size to be used in the variation of XC and YC in the search procedure for the minimum factor of safety; dimension - feet
EO	- initial void ratio; in the case of two layers, EO applies to the upper layer
FSI	- factor of safety which is required at the time of application of a new load
GAMMA	- effective unit weight of the subsoil, constant over the thickness of the compressible layer; this value is needed in the settlement computations using the compression index; if GAMMA=0, input of MYE effective overburden stresses at equally spaced depths must be input; dimension - pcf
GLOAD	- unit weight of the embankment soil, dimension - pcf
GRID	- symbol to be used in the resulting plots to mark the 10% coordinates; proposed to be the letter I
H	- thickness of the compressible layer; if H=0, the program is terminated;

if H=99, a branch is made to the beginning of the programs; dimension - feet

HC - Henry's constant of gas solubility, HC=0.020 for atmospheric air, HC=0.029 for methane, HC=2.84 for hydrogen sulfide (at 68°F)

HI - thickness of the "impedance layer" underlying the compressible soil; the "impedance layer" must have a freely draining lower surface, a coefficient of compressibility which is negligibly small compared to that of the consolidating soil, and a permeability of the same order of magnitude as that of the consolidation soil; dimensions - feet

IAB - identifier where -
- IAB=0 - Skempton's pore pressure coefficients A and B as defined for the last load are also used to compute the pore water pressures due to the load addition
- IAB=1 - redefine A and B

IAV - identifier where -
- IAV=0 - use a constant coefficient of compressibility in the settlement computations
- IAV=1 - use the compression indices in the settlement computations

IBCV - identifier where -
- IBCV=1 - impeded vertical drainage at the bottom of the consolidating layer
- IBCV=2 - free vertical drainage at the bottom of the consolidating layer
- IBCV=3 - no vertical drainage at the bottom of the consolidating layer

ICV - number of data pairs (PCV(I),CVIN(I)) and (PCR(I),CRIN(I)) through which Lagrangean interpolation polynomials are passed; $0 < ICV \leq 10$

IDEN(I) - identifier corresponding to the I-th load step, where

IDEN(1)<0 - the excess pore water pressures due to the first load step are set equal to the input residual pore water pressures
IDEN(I)=0 - the excess pore water pressures due to the I-th load are computed by means of subroutine PORE
IDEN(I)=1 - the excess pore water pressures due to the I-th load are set equal to those computed for the reference load. Note, that this requires that Skempton's coefficients A and B are identical in both cases;
IDEN(1)<0 allows the check of an existing installation for which the excess pore water pressures just after load application are known from field measurements; I=1, NL

IEND - number of horizontal coordinates XT; IEND is computed, if ISP=0; IEND ≤ 20

IK - identifier where
IK=0 - constant coefficients of permeability
IK=1 - the radial and vertical coefficients are variable; the void ratio versus the logarithm of the coefficient of permeability is a straight line

IRP - identifier where
IRP=0 - no residual pore water pressures are input
IRP=1 - residual pore water pressures at points (W·XT, H·YE) are input columnwise
IRP=2 - residual pore water pressures at arbitrary points are input

ISAT - identifier where
ISP=0 - settlements, the process of consolidation, and the stability are analyzed; in program SAND, the times at which a new load step can be applied are determined;
ISP=1 - settlements and the process of consolidation are analyzed, and the times of load application are required as input parameters in program SAND; ISP=1 also requires the output of the time-dependent pore water pressures at MRE·MYE

points of the solution domain of the sand drain installations with axes at the user-defined locations XT

ITBL - number of times TB(I), defined in a DATA-statement, for which the pore water pressures and settlements are determined; times TB always start at the time of application of a new load step in SAND; ITBL ≤ 45

IVAR - identifier where
IVAR=0 - use constant coefficients of consolidation
IVAR=1 - use variable coefficients of consolidation which are obtained either by interpolation between CHIN(I) and CVIN(I) or by varying the coefficient of compressibility and/or the coefficients of permeability

JND - number of points for which output is required JND ≤ 10

JSP(I) - indices of the JND points for which output is required; I=1, JND ≤ 10; the output is for points XE (JSP(I)), where XE and MX equally spaced coordinates between and including the limits W·AX(1) and W·AX(NI); for example, specification of JSP(1)=1 and JSP(JND)=MX causes the output of information at the limits W·AX(1) and W·AX(N1), respectively

KHO - initial coefficient of permeability in the horizontal direction; dimension - ft/day

LAYER - number which indicates the location of a layer interface; LAYER=KK means that the layer interface is located at a depth below ground surface which is equal to Y=H*(KK-1)/(MYE-1); if only one layer is to be considered, set LAYER=0; the program requires that 3 ≤ LAYER ≤ (MYE-3); LAYER causes a layer interface to be considered in the consolidation and the settlement analyses only

LND - number of weeks to be plotted on the time axis of the output figures

MINP - number of points defining the contour of the embankment load; MINP ≤ 20

MHE - number of equally spaced points in the horizontal direction; MHE < 40

MX - number of equally spaced points XE in the horizontal direction between the limits AX(1) and AX(NI); MX < 51

MXT(I) - number of unequally spaced points XT between the consecutive limits AX(I) and AX(I+1); I=1, (NI-1) < 4; maximum value of any MXT(I) must be values MXT(I) must not exceed IEND=20

MYE - number of equally spaced points in the vertical direction, including the surface and the bottom of the compressible layer; MYE < 12

NC - number of initial undrained shear strengths, CO(I), and $(c/\bar{p})$-ratios, CP(I); NC < MYE < 11

NI - number of interval limits AX(I); NI < 5

NL - number of load steps; NL < 6

NRAD - number of trial arcs to be used with each trial center (XC,YC) in the stability analysis; NRAD > 1

NS - number of load strips used to approximate the actual embankment load; NS < 20

P(I) - present overburden effective stresses at MYE equally spaced depths, including the surface; I=1, MYE < 12; dimension - psf

PC(I) - preconsolidation stresses at MYE equally spaced depths, including the surface; I=1, MYE < 12; dimension - psf

PCH(I) - effective stresses at which the horizontal coefficients of consolidation, CHIN(I), are defined; I=1, ICV < 10; dimension - psf

PCV(I) - effective stresses at which the vertical coefficients of consolidation, CVIN(I), are defined; I=1, ICV < 10; dimension - psf

PU	- initial pore gas pressure; if PU is not defined during input, it is set equal to the sum of the atmospheric pressure plus one-half the thickness of the compressible layer times the unit weight of water; dimension - psf
RAV	- coefficient of compressibility of the lower layer divided by that of the upper layer
RC	- vertical coefficient of consolidation of the lower layer divided by that of the upper layer
RCC	- virgin compression index of the lower layer divided by that of the upper layer
REO	- initial void ratio of the lower layer divided by that of the upper layer
RK	- vertical coefficient of permeability of the lower layer divided by that of the upper layer note, if RC and RAV are specified, RK=RC*RAV*(1+EO)/(1+EO*REO)
RKV	- vertical coefficient of permeability of the consolidating soil divided by that of the underlying impedance layer
ROC	- recompression index divided by the virgin compression index; in case of two layers, ROC applies to the upper layer
ROCL	- recompression index of the lower layer divided by the virgin compression index of the upper layer
S	- degree of saturation to be input as a decimal fraction
SKH	- slope of the void ratio versus the logarithm of the horizontal coefficient of permeability curve
SKV	- slope of the void ratio versus the logarithm of the vertical coefficient of permeability curve
SPECS	- fraction of the consolidation settlement due to the reference load; this settlement must have occurred before a new load is applied (program SAND)
SPECU	- when the non-dissipated average pore water pressures become less than 5% of the total average

pore water pressures existing just after application of the last load at IEND*SPECU points XT, subsequent loads are disregarded; the rationale for this procedure is that no significant increase in strength and/or settlement can be expected after an average degree of consolidation of 95% has been reached under the applied load at a number of points; in selecting the magnitude of SPECU, which is input as a decimal fraction, it should be noted that the degrees of consolidation in the case of constant coefficients of consolidation will be the same for different points XT, as long as the drainage boundary conditions are the same

STAR - symbol to be used in the resulting plots to mark the coordinate axes; proposed to be the asterisk *

SYMB(I) - symbols to be used in the resulting plots to present points of the computed curves; the letters U, C, O, and T are proposed for the average decree of consolidation, the consolidation settlement, the initial, and the total settlement versus time curves, respectively. It should be noted that T plots on top of O, which plots on top of C, which plots on top of U; this means, that only T will show, when the four values are identical; I=1,2 in the case of complete saturation, and I=1,4 in the case of partial saturation
User can use any other letters as symbols

TA - available construction time; in SAND, this is the time at which the final load must have been applied; dimension - days

TGPHI - tangent of the angle of internal friction of the drainage blanket, if there is one

TL(I) - times of load application in the case where ISP=1; I=1, NL $\leq$ 6; dimension - days

TMIN - time which must have passed after a load application before the first stability analysis is made to determine, whether the next load can be applied; dimension - days

U* - residual pore water pressure; dimension - psf

W - reference value in the horizontal direction; dimension - feet

X* - horizontal distance from the center line at which the residual pore water pressure is known; dimension - feet

XC - X-coordinate of the center of the first trial arc; if XC=0 is input, the programs select a starting value; dimension - feet

XINP(I) - X-coordinates of the points defining the embankment contour; I=1, MINP < 20; dimension - feet

XT(I) - X-coordinates of the points at which the settlements and the consolidation behavior are determined; if ISP=0, XT(I) are computed for I=1 through MXT(J); if ISP=1, XT(I), I=1, IEND < 20 are input as fractions of W

Y* - vertical distance below the ground surface at which the residual pore water pressure U is known; positive downward; dimension - feet

YC - Y-coordinate of the center of the first trial arc; positive upward; dimension - feet

YINP(I) - Y-coordinates of the points defining the embankment contour; positive upward; I=1, MINP < 20; dimension - feet

YWM - thickness of a drainage blanket placed on the surface of the compressible soil layer; dimension - feet

ZZ - distance between the maximum YINP(I) and the minimum value YC permissible in the stability analyses; dimension - feet

---

* The residual pore water pressures are first arranged such that points having the same X-coordinate are grouped in the order of ascending Y-coordinates. Data sets are then input in the order of ascending X, whereby the last card is identified by COUNT ≠ 0.

Method

The programs facilitate the analysis of an embankment foundation on a soft, compressible soil layer, which is underlain by a firm stratum. The approach involves the consideration of the following problems: (a) stress and pore pressure distribution within the soft layer due to a symmetrical vertically acting embankment load at the surface, (b) the dissipation of excess pore water pressures subject to different flow conditions including horizontal flow, (c) the computation of settlements, and (d) the stability of the embankment-subsoil system with consideration of the gain in shear strength as consolidation proceeds.

The programs are designed to solve several cases during the same program execution, wherefore some computations are performed before data for a specific case are input. To save computer time and storage, computations are only done for a limited number of locations in the horizontal direction, and information at intermediate points is obtained by interpolation.

PROGRAM SAND -- After computation of the pore water pressures and settlements due to a reference load, which in most cases will be identical with the final load, essentially two options are available by means of index ISP. If ISP=0, the embankment contours of the different load steps are input and the program determines the times at which new load steps can be applied. The criteria incorporated into the programs are: (1) a defined portion of the reference settlement at the point closest to the center line of the embankment must have occurred, and/or

(2) a specified factor of safety must be assured at the time of a new load application. To avoid unnecessarily numerous stability analyses stability analyses, a time TMIN measured from the last load application can be defined, and stability analyses are not performed for times less than TMIN, although settlements and degrees of consolidation are computed. For the same reason, the program contains the restriction that all subsequent load steps are disregarded if 95% consolidation has occurred at a specified number of points under the acting load. The rationale is that only a minor increase in strength and settlements can be expected due to dissipation of the remaining excess pore water pressures, and the times required will likely be prohibitive.

If ISP=1, the different load contours, as well as the times of load application, must be input, and the program analyzes the consolidation process and the settlements without performing any stability analyses. Use of ISP=1 also produces the output of the pore water pressures at MYE*IEND points of a vertical cut through the locations XT˙W.

The computed information is first stored internally on two internal files for each step of load. A total of 6 steps of loads are allowed.

The program can handle analysis of multiple embankments in a single run. This is done by putting H = 99 at the end of the data cards for the previous embankment. On the other hand by specifying H = 0 the program is terminated.

The output, in addition to that given for ISP=0, includes the excess pore water pressures at MYE*JND points of a vertical section through the subsoil.

Remarks

The average degree of consolidation is defined in the programs as the integral over the dissipated pore water pressures divided by the integral over the excess pore water pressure build-up under the reference load.

The increase in the effective stresses at the time of load application in the case of a partially saturated soil is assumed to be equal to the difference between the pore water pressures obtained for B=1.0 and B<1.0, where B is Skempton´s pore pressure coefficient.

To account for the fact that the swelling index is normally considerably smaller than the compression index, negative pore water pressures, which might result after surcharge removal, are neglected in program SAND.

Subroutines Required

```
COEF (UAVD,UAVE,OMEGA,PHI,LI,IL,OMED,PHID,NN)
DISP (U,LI,OMEGA,PHI,T,UAVE,LIFT,MYE,IEND,XT,SV)
GAIN (UA,R,SU,MYE,MXT,MXE,MX,NIM,CO,CP,III)
GENS (S,M)
INIT (XINP,YINP,MINP,XC,YC,YY,ZZ,DMIN)
LAGR (X,Y,M,JST,XX,YY,N)
```

```
MATR (IS,IE,M,XV,A,XM)
MINV (A,N,D)
MPRD (A,B,R,N,M,L,IAS,IBS,IRS)
PORE (XINP,YINP,M,NST,CX,IX,CY,IY,U,ABAR,BBAR)
SETL (U,SETTL,IEND,KKK,MYE,F,FUP,FLO,KIAV)
STAB (XC,YC,R,XINP,YINP,MINP,MX,MYE,SU,FX,D,DM,YY)
```

2.2 Subroutine APROX

Purpose

To approximate the embankment contour by a number of strips of constant thickness

Usage

CALL APPROX (X,Y,MN,N,D)

Block Names

POAPI/ALPHA(30),L

Description of Parameters

- X,Y - coordinates of the points defining the embankment contour; must be provided such that X(1)=0<X(2)<......<X(MN)
- MN - number of points X,Y; MN ≤ 20
- N - number of approximating strips
- D - thickness of the approximating strip
- ALPHA - returned lengths of the strips
- L - number of values ALPHA, L ≤ 30

Statement Functions Required

CONK(KO,SKM);VARK(KO,SKM);PSI(AA,K)

2.3 Subroutine DETFS

Purpose

To determine the factor of safety of an embankment resting on a soft subsoil.

Usage

```
CALL DETFS(XC,YC,R,XINP,YINP,MINP,MX,MYE,SU,FS)
```

Block Names

```
INDET/RHO(19),TAU(19),PSI(19)
SAPOD/IOUTP*;W*;H*;GLOAD,CLOAD,NARC,NRAD*
SADET/XSTAB(51),YSTAB(11),DX,DY,YWM,TGPHI
```

* Parameters marked by an asterisk are not needed in this subroutine

Description of Parameters

XC	- X-coordinate of the center of the circular slip surface
YC	- corresponding Y-coordinate
R	- radius of the circular slip surface
XINP	- X-coordinates of the points defining the embankment contour
YINP	- corresponding Y-coordinates
MINP	- number of points (XINP,YINP)
MX	- number of equally spaced grid points in the X-direction

MYE	-	number of equally spaced grid points in the Y-direction
SU	-	undrained shear strengths at (MX*MYE) grid points
FS	-	factor of safety to be provided
RHO	-	slopes of the lines connecting consecutive points XINP/YINP
TAU	-	parameters defined in subroutine INIT; $TAU=1+RHO^2$
PSI	-	Y-value at X=0 for the lines connecting consecutive points XINP/YINP
GLOAD	-	unit weight of the embankment soil
CLOAD	-	undrained strength of the embankment soil
NARC	-	one-half the number of subarcs within the subsoil
XSTAB	-	X-coordinates of the grid points
YSTAB	-	Y-coordinates of the grid points
DX	-	interval in the X-direction
DY	-	interval in the Y-direction
YWM	-	thickness of the drainage blanket
TGPHI	-	tangent of the angle of internal friction of the soil in the drainage blanket

Method

A total stress analysis is performed to evaluate the factor of safety of an embankment which consists of cohesive soil and a cohesionless drainage blanket. The undrained strengths of the subsoil are input at MX*MYE grid points, and the strength available along the portion of the circular slip surface that passes through the subsoil is obtained at the centers of 2*NARC subarcs

by interpolation between the strengths SU at adjacent grid points. Resisting the driving moments are first computed with the assumption that the embankment consists entirely of frictionless soil. The so-obtained ratio of moments is then used as the initial estimate in the iteration for the correct factor of safety, in which the drainage blanket is considered.

Statement Functions Required

FUNA (A,B), FUNB (B), FUNC (A,B,C)

Remarks

The coordinates YINP,YC,YWM and PSI are positive upward, wherein YSTAB is positive downward with the coordinate origin at the surface of the soft layer.

2.4 Subroutine DISP

Purpose

To determine the excess pore water pressures at arbitrary times for step loading conditions.

Usage

```
CALL DISP(U,LI,OMEGA,PHI,T,UAVE,LIFT,MYE,IEND,XT,SV)
```

Block Names

```
SAPOD/IOUTP,W*,H*,GLOAD*,CLOAD*,NARC*,NRAD*;
SADI1/LAYER,IBCV,MHE,M,N,IDC,NDR,ISUM,XET(41);
```

SADI2/FIMPV,RC,RK,C,RO,RE,TA,ISP,IVAR;
* parameters marked by an asterisk are not needed in this subroutine

Description of Parameters

U	- pore water pressures to be determined; for LI=1,5,6 this vector contains the additional pore water pressures for the new load, when subroutine DISP is called
LI=1	- determines vectors A and B for the load addition
LI=2	- determines the pore water pressures due to step-wise constant loads
LI=3	- determines vectors A and B for times between load applications in the case where the "consolidation factor" is variable
LI=5	- first lift; first execution of subroutine DISP
OMEGA	- "consolidation factors" for radial flow; product of the gas factor and the radial coefficient of consolidation
PHI	- "consolidation factors" for vertical flow; product of the gas factor and the vertical coefficient of consolidation
T	- time
UAVE	- average pore water pressures
LIFT	- number of lifts applied at and before time T
MYE	- number of points equally spaced in the vertical direction at which the pore water pressures are computed
MHE	- number of points equally spaced in the horizontal direction at which the pore water pressures are computed ≤ 40
IEND	- number of elements in vectors OMEGA,PHI,UAVE and XT

XT - points in the horizontal direction for which OMEGA and PHI are input and UAVE is computed

SV - mathematical molecule of the extended Simpson's or trapezoidal rules in the vertical direction

IOUTP - logical output unit

LAYER - index indicating the depth of a layer interface; LAYER > 3

IBCV=1 - vertical drainage; impeded drainage at the lower boundary surface

IBCV=2 - vertical drainage; free drainage at the lower boundary surface

IBCV=3 - vertical drainage; no drainage at the lower boundary surface

M - number of eigenvalues for the vertical problem

N - number of eigenvalues for the horizontal problem

IDC=1 - vertical flow only at all points XT

IDC=2 - vertical plus horizontal flow at all points XT

ISUM - number of elements of vector U

FIMPV - "impedance factor" for vertical flow; FIMPV= (RKV*HI/DY) / (1.+RKV*HI/DY), as defined in SAND

RC - ratio of the vertical coefficients of consolidation of the lower and upper layer

RK - ratio of the vertical coefficients of permeability of the lower and upper layer

ISP=1 - compute and print the pore water pressures at all MYE*MRE points of the solution domain for IEND locations XT; return the averages taken at MYE depths over the circular area of influence as vector U; return the overall average at IEND locations XT as vector UAVE

ISP=0 - suppress the printing

IVAR=0 - constant "consolidation factors"

IVAR=1 - variable "consolidation factors"

Method

The consolidation problem is treated as an eigenvalue problem.

Subroutines Required

```
EFGEN(PSI,T,EIG,IVAR,MM,NN,D,LI)
MAMUL(A,D,B,C,N,IS,II)
MODAL(LAYER,IBC,N,FIMP,RC,RK,XO,XE,EIG,X,XI,F)
MPRD(A,B,R,N,M,L,IAS,IBS,IRS)
```

Remarks

Storage reservations are made to account for IEND $\leq$ 40 and a maximum of 6 step loads.

2.5 Subroutine LINT

Purpose

To interpolate between arbitrarily spaced data points by use of interpolation or extrapolation.

Usage

```
Call LINT(X,Y,N1,M,XX,YY,N)
```

Description of Parameters

X - vector of arguments for which the values of the function are interpolated

Y - resulting vector of interpolated values of the function

N1 - number of arguments in X

M - index of the last value of Y

XX - vector of arguments for which the values of the function are known

YY - vector of known values of the function

N - number of arguments in XX

2.6 Subroutine HDIST

Purpose

To calculate the horizontal distance from the CL to the point where the pore pressure is 0.1% of the maximum pore pressure under the embankment.

Usage

```
Call HDIST(UB,XT,IEND,ICV,CHIN,DXSQ,AAH,MHE,W,
     XET,IPOR,HF,MYE,POR)
```

Description of Parameters

UB - pore pressure at (MYE*IEND) points under the embankment

XT - X-coordinate of the points at which the settlements and consolidation behavior are determined

IEND - number of horizontal coordinates XT

ICV - number of data pairs (PCV(I),CVIN(I)) and (PCH(I),CHIN(I)) through which Lagrangian interpolation polynomials are passe

CHIN - variable coefficient of consolidation in horizontal direction

DXSQ - (DELTA H** 2.)

AAH - (1.+EO)/(GAMMA WATER x (DELTA H) ** 2.)

MHE - number of horizontal grid points

W - Reference width

XET - X-coordinates of the equidistant points in the horizontal direction

IPOR - indicator to specify the value of POR
=1 , POR is specified by the user
=0 , program evaluates POR

HF - =1 , If horizontal flow is considered
=0 , If no horizontal flow is allowed

MYE - number of points in the vertical direction

POR - horizontal drainage distance/[XT(IEND)*W]

2.7 Subroutine COEF

Purpose

To determine the gas factor and the coefficients of consolidation.

Usage

COEF-UAUD,UAVE,OMEGA,PHI,LI,IL,OMED,PHID,NN]

Block Names

SACSE/ROC,ROCL,SVM,P,PC,PLOQ,PO,PCO,LAV,IK,ISAT,AAV,AAH
SACO1/AVO,KVO,KHO,EOPUS,PU,SKHM,SKVm,CCC,NNN,ICOEFF
SACO2/PCV(10),CXIN(10),PCR(10),CHIN(10),ICV,KOUNT,HF

Description of Parameters

UAVD	-	average pore pressure before consolidation
UAVE	-	average pore pressure at some time after consolidation
OMEGA	-	consolidation factors of horizontal flow, product of the gas factor and the horizontal coefficient of consolidation
PHI	-	consolidation factor for vertical flow, product of the gas factor and the vertical coefficient of consolidation
IL	-	indicator =1 - calculate the parameters for vertical flow ≠1 - calculate the parameters for horizontal flow
LI	-	identifier; if LI=3, OMED and PHID are computed
NN	-	number of points where OMEGA,PHI,OMED and PHID are required
OMED	-	difference between the radial consolidation factor computed in a previous execution of this subroutine and the value computed in this execution of the subroutine
PHID	-	difference between the vertical consolidation factor computed in a previous execution of this subroutine and the value computed in this execution of the subroutine
IEND	-	number of elements in arrays UAVD,UAVE,OMEGA,PHI, OMED,PHID
ROC	-	ratio between the recompression and the virgin compression indices
PO	-	average initial vertical effective stress
PCO	-	average preconsolidation stress
IAV=0	-	constant coefficient of compressibility

IAV=1 - variable coefficient of compressibility

IK=0 - constant coefficient of permeability

IK=1 - variable coefficient of permeability

ISAT=0 - 100% saturation

ISAT=1 - partial saturation

AAV - factor defined in program SAND; AAV=(1+EO)/(62.43*DY^2)

AAH - factor defined in program SAND; AAH=(1+EO)/(62.43*DH^2)

AVO - initial or constant coefficient of compressibility

KVO - initial coefficient of permeability in the vertical direction

KRO - initial coefficient of permeability in the radial direction

EOPUS - factor defined in program SAND; EOPUS=EO*PU*(1-S)*(1-HC)

PU - initial pore gas pressure

SKVM - factor defined in program SAND; SKVM=CC/SKV, if IAV=1 and SKVM=2.3026*AVO/SKV, if IAV=0

SKHM - factor defined in program SAND; SKHM=CC/SKH, if IAV=1 and SKRM=2.3026*AVO/SKH, if IAV=0

CCC - compression index times 0.4343

NNN - number of locations with radial and vertical drainage conditions

ICOEF=1 - IK=0, IAV=0 or IAV=1

ICOEF=2 - IK=1, IAV=0

ICOEF=3 - IK=1, IAV=1

ICOEF=4 - the coefficient of consolidation is obtained by interpolation

PCV - effective stresses for which the vertical coefficients of consolidation are input

CVIN - vertical coefficients of consolidation at PCV

PCH - effective stresses for which the radial coefficients of consolidation are input

CHIN - radial coefficients of consolidation at PCH

ICV - number of PCV,CVIN,PCR, and CRIN; ICV ≤ 10

KOUNT=0 - second or subsequent executions of this subroutine

KOUNT=1 - first use of this subroutine

Method and Reference

Depending on the values of the indices ISAT,IK,IAV, and ICOEF, the values of the "consolidation factors" for radial and vertical flow are determined for the average increases in effective stresses (UAVD-UAVE) at IEND locations. Relationships considered include: (bi-) linear void ratio versus logarithm of effective stress or constant coefficient of compressibility; linear void ratio versus logarithm of coefficient of permeability; and arbitrary coefficient of consolidation versus effective stress relationships.

2.8 Subroutine EFGEN

Purpose

To generate the time-dependent matrix D.

Usage

```
CALL EFGEN(PSI,T,EIG,IVAR,MM,NN,D,LI)
```

Description of Parameters

PSI	-	vector containing MM "consolidation factors"
T	-	time at which diagonal matrix D is computed
EIG	-	vector containing the eigenvalues
IVAR=0	-	constant "consolidation factor"; PSI consists of one element only
IVAR=1	-	variable "consolidation factor"; PSI consists of MM elements
MM	-	number of elements PSI (in most other routines, this parameter is called IEND)
NN	-	number of eigenvalues
D	-	diagonal matrix to be determined

Method

The elements of the diagonal matrix D are given by exp (PSI(J)*EIG(I)*T), wherefore D has a total of MM*NN elements. However, if IVAR=0, D(K)=D(K+NN)=...=D(K+(MM-1)*NN).

2.9 Subroutine GAIN

Purpose

To determine the gain in shear strength.

Usage

CALL GAIN(UA,R,SU,MYE,MXT,MXE,MX,NIM,CO,CP,III)

Description of Parameters

UA	-	vector of dissipated pore water pressures at points (XT,XE)
R	-	auxiliary matrix necessary to compute the dissipated pore water pressures at points (XE,YE) from a knowledge of those at points (XT,YE)
SU	-	resultant undrained strengths at points (XE,YE)
MYE	-	number of equally spaced points in vertical direction
MXT(I)	-	number of points XT between the interval limits AX(I) and AX(I+1)
MXE(I)	-	number of points XE between the interval limits AX(I) and AX(I+1)
MX	-	sum of MXE(I) for I=1,NIM
NIM	-	number of subintervals
CO	-	vector containing MYE undrained initial shear strength values
CP	-	vector containing MYE $(c/\overline{p})$-ratios
III=1	-	all elements of array UA are assumed to be equal to zero
III=0	-	some or all elements of array UA differ from zero

Method

The strength values SU are obtained as the sum of the initial shear strengths plus the products of the $(c/\overline{p})$-ratios and the dissipated pore water pressures.

2.10 Subroutine FUNCT

Purpose

This subroutine computes the values of the integrands for the argument theta.

Usage

CALL FUNCT(THETA,ETA,K,SIGX,SIGY,TAU)

Block Names

POFUN/Q(258),ETHST(258)

Description of Parameters

K	-	index necessary to select the proper quantities Q and ETH, which have been precomputed for the same argument THETA
SIGX	-	value of the integrand of the equation for the horizontal normal stress
SIGY	-	value of the integrand of the equation for the vertical normal stress
TAU	-	value of the integrand of the equation for the shear stress
Q	-	precomputed vector whose elements are equal to the sum of $(\sin \alpha_1 \theta)/\theta$
ETH	-	precomputed vector whose elements are equal to $\exp(\theta)$

Method

The subroutine makes use of the fact that the hyperbolic sine and cosine functions can be expressed in terms of the exponential function.

2.11 Subroutine GENER

Purpose

To determine the coefficients and the roots of the characteristic equation.

Usage

```
CALL GENER(P,F,X,N)
```

Description of Parameters

P - tridiagonal matrix whose lower off-diagonal elements are equal to -1.0

F - auxiliary matrix used during the computations

X - roots of the characteristic equation; these are the eigenvalues

N - degree of the characteristic equation

Subroutines Required

RROOT (A,X,N)

2.12 Subroutine GENS

Purpose

To generate the mathematical molecules which are used in a numerical integration.

Usage

```
CALL GENS(S,M)
```

Description of Parameters

S - resulting mathematical molecule

M - number of pivotal points

Method

For the case of vertical flow, the elements of vector S are either computed by the extended Simpson rule or the extended trapezoidal rule assuming equal spacing; the use of Simpson's rule requires that M be an odd number.

2.13 Subroutine INIT

Purpose

To select starting values for the stability analysis and define three vectors which are repeatedly used in subroutine DETFS.

Usage

```
CALL INIT(XINP,YINP,MINP,XC,YC,YY,ZZ,DMIN)
```

Block Names

```
SAPOD/IOUTP*,W*,H,GLOAD*,CLOAD*,NARC*,NRAD*;
INDET/RHO(19),TAU(19),PSI(19);
* parameters marked by * are not needed in this routine
```

Description of Parameters

XINP - X-coordinates of the points defining the embankment contour

YINP - Y-coordinates of the points defining the embankment contour

MINP - number of points (XINP,YINP)

XC - X-coordinate of the center of the first trial slip surface

YC - corresponding Y-coordinate

YY - minimum permissible value for YC

ZZ - difference between the maximum YINP-value and YY

DMIN - minimum increment to be used in the direct search procedure

H - thickness of the compressible layer

RHO - slopes of the lines which connect consecutive points (XINP,YINP)

TAU - TAU=1+RHO**2

PSI - Y-value at X=0 for the lines connecting consecutive points (XINP,YINP)

Method

When the center of the first trial failure arc is not input from SAND, YC is set equal to YY and XC is defined as one-half of the sum of the X-values obtained when two circles with radius R=YY+H pass through (XINP(1),YINP(I)) and the toe of the embankment, respectively. The vectors RHO, TAU, and PSI are computed once for repeated use in subroutine DETFS

2.14 Subroutine INTEG

Purpose

To compute approximate values of the stress integrals between the limits B and infinity.

Usage

CALL INTEG(ETA,XI,B,AR)

Block Names

PCAPI/ALPHA(30), L;

Description of Parameters

ETA	-	Y-coordinate divided by the thickness of the compressible layer
XI	-	X-coordinate divided by the thickness of the compressible layer
B	-	lower integration limit
AR	-	resulting array with six integral values
ALPHA	-	length of the load strips divided by the thickness of the compressible layer
L	-	number of ALPHA´s

2.15 Subroutine LAGR

Purpose

To interpolate between arbitrarily spaced data points by use of the Lagrangean polynomial.

Usage

CALL LAGR(X,Y,M,JST,XX,YY,N)

Description of Parameters

X	-	vector of arguments for which the values of the function are interpolated
Y	-	resulting vector of interpolated values of the function
X	-	number of arguments X
JST	-	index of the first value Y to be interpolated
XX	-	vector of arguments for which the values of the function are known
YY	-	vector of known values of the function
N	-	number of arguments XX

Method

A Lagrangean polynomial of degree (N-1) is passed through the data points (XX,YY) and then evaluated for M arguments X. See, for example, the book by CARNAHAN, LUTHER, AND WILKES (1969).

2.16 Subroutine MAMUL

Purpose

To perform the matrix multiplication: (general matrix)* (diagonal matrix)*(column vector).

Usage

CALL MAMUL(A,D,B,C,N,IS,II)

Description of Parameters

A - general square matrix

D - diagonal matrix

B - column vector

C - resulting column vector

N - order of matrices A and D and length of vectors B and C

IS - index of the first element of vector B

II - index of the first element of matrix D, whose diagonal elements only are stored one-dimensionally

Method

The subroutine utilizes the fact that all matrices are stored one-dimensionally, so that the I-th element of vector C becomes

$$C(I)= \sum_{K=1}^{N} A(I+K^{*}N-N)*B(IS-1+K)*D(II-1+K)$$

2.17 Subroutine MATR

Purpose

To generate matrix XM, the elements of whose rows are equal to integer powers of the differences between the elements of vector XV and constant A.

Usage

CALL MATR(IS,IE,M,XV,A,XM)

Description of Parameters

IS	-	index of the first element of vector XV
IE	-	index of the last element of vector XV
M	-	number of rows of matrix XM
XV	-	vector with (IE-IS+1) elements
A	-	constant to be subtracted from all elements XV
XM	-	resulting M by (IE-IS+1) matrix

Method and Reference

Given the vector XV with elements XV(IS),XV(IS+1),...,XV(IE), the M by (IE-IS+1) matrix is generated and stored one-dimensionally, such that XM (K+I*M-M)=(XV(IS+I-1)-A)**(K-1).

Program Length

45 words

2.18 Subroutine MINV

Purpose

To invert a general matrix.

Usage

CALL MINV(A,N,D)

Block Names and Lengths

None

Description of Parameters

A - input matrix destroyed in computation and replaced by the resultant inverse

N - order of matrix A; N $\leq$ 25

D - resulting determinant

Method and Reference

The standard Gaub-Jordan method is used. This subroutine is a slightly modified version of subroutine MINV, as given in the IBM Application Program, 1130 Scientific Subroutine Package (1130-CM-02X), Programmer's Manual, Form H20-0252-0, White Plains, New York, 1966.

2.19 Subroutine MODAL

Purpose

To determine matrix P, its eigenvalues, the corresponding modal matrix, and the inverse of the modal matrix.

Usage

```
CALL MODAL(LAYER,IBC,N,FIMP,RC,RD,XO,XE,EIG,X,XI,F)
```

Description of Parameters

LAYER=1	- radial drainage conditions
LAYER=2	- vertical drainage conditions; homogeneous soil profile
LAYER > 3	- vertical drainage conditions; two-layered soil profile with layer interface at YE(LAYER)
IBC=1	- vertical flow; impeded drainage at the bottom
IBC=2	- vertical flow; free drainage at the bottom
IBC=3	- vertical flow; no drainage at the bottom
N	- number of eigenvalues
FIMP	- "impedance factor"; for vertical flow (RKV*HI/DY)/(1.+RKV*HI/DY)
RC	- ratio of the vertical coefficients of consolidation of the lower and the upper layers
RK	- ratio of the vertical coefficients of permeability of the lower and the upper layers
XO	- lower boundary of the solution domain
XC	- upper boundary of the solution domain
EIG	- resultant eigenvalues
X	- resultant modal matrix

XI - inverse of the resultant model matrix

F - auxiliary matrix

Method and Reference

For IBC=2 and IBC=3, the eigenvalues and the modal matrix can be computed directly for a homogeneous soil profile. In all other cases, the auxiliary matrix D and matrix P, whose eigenvalues are determined in subroutine GENER, must be generated before the modal matrix X can be set up. Finally, the inverse of the modal matrix is computed by use of subroutine MINV.

Subroutines Required

GENER(P,F,X,N)
MINV(A,N,D)

Remarks

The lower off-diagonal elements of matrix P, which are equal to -1.0, are not stored.

2.20 Subroutine MPRD

Purpose

To multiply two matrices to form a resultant matrix.

Usage

CALL MPRD(A,B,R,N,M,L,IAS,IBS,IRS)

Description of Parameters

A	-	first input matrix
B	-	second input matrix
R	-	output matrix
N	-	number of rows of matrices A and R
M	-	number of columns of matrix A and number of rows of matrix B
L	-	number of columns of matrices B and R
IAS	-	index of the first element of matrix A
IBS	-	index of the first element of matrix B
IRS	-	index of the first element of matrix R

Method

The M by L matrix B is premultiplied by the N by M matrix A and the result is stored in the N by L matrix R. The indices IAS,IBS, and IRS allow the multiplication of submatrices of A and B, and the product is stored as a submatrix of R.

Remarks

Matrix R cannot be in the same location as matrices A or B.

2.21 Subroutine PORE

Purpose

To compute the elastic stresses and pore water pressures within a layer of finite thickness for a symmetrical vertical load.

Usage

```
CALL PORE(XINP,YINP,M,NST,CX,IX,CY,IY,U,ABAR,BBAR)
```

Block Names

```
SAPOD/IOUTP,W,H,GLOAD,CLOAD*,NARC*,NRAD*
POAPI/ALPHA(30),L;
POFUN/QST(129),ETHST(129);
```

* parameters marked by an asterisk are not needed in this subroutine

Description of Parameters

XINP	-	X-coordinates of the points defining the embankment contour
YINP	-	corresponding Y-coordinates
M	-	number of points (XINP,YINP)
NST	-	number of approximating load strips
CX	-	X-coordinates divided by the reference value W, for which the stresses are to be computed
IX	-	number of CX-values
CY	-	Y-coordinates divided by the thickness of the compressible layer H, for which the stresses are to be computed
IY	-	number of CY-values
U	-	resulting excess pore water pressures (IX*IY $\leq$ 220 elements)
ABAR	-	Skempton's pore pressure coefficient A
BBAR	-	Skempton's pore pressure coefficient B
IOUTP	-	logical output unit

W - reference length in X-direction

H - thickness of the compressible layer

GLOAD - unit weight of the embankment soil

ALPHA - lengths of the load strips which approximate the actual embankment load

L - number of values ALPHA

QST - resulting vector whose elements are repeatedly used in subroutine FUNCT

ETH - resulting vector whose elements are repeatedly used in subroutine FUNCT

Method and Reference

The total stresses within a compressible layer are computed by use of elastic theory for plane strain conditions and a symmetric vertical loading. Poisson´s ratio is set equal to 0.5, and the underlying stratum is assumed to be rough and rigid. Because of the complex nature of the stress integrals, a numerical integration procedure, based on either Simpson´s rule of Filon´s formulae, has been chosen for their evaluation.

Subroutines Required

APROX(X,Y,MN,N,D)
FUNCT(THETA,ETA,K,SIGX,SIGY,TAU)
INTEG(ETA,XI,B,AR)

Remarks

The coordinates YINP are positive upward, whereas ETO is positive downward with the coordinate origin at the surface of the compressible layer. ETA is positive upward with the origin at the bottom of the compressible layer.

2.22 Subroutine RROOT

Purpose

To compute the real roots of the characteristic equation.

Usage

```
CALL RROOT(COF,XR,M)
```

Description of Parameters

COF	- input vector containing the (M+1) coefficients of the polynomial
XR	- resulting M roots of the polynomial
M	- degree of the polynomial

2.23 Subroutine SETL

Purpose

To compute settlements for constant or variable coefficients of compressibility.

Usage

```
CALL SETL(U,SETTL,IEND,KKK,MYE,F,FUP,FLO,KIAV)
```

Block Names and Lengths

SACSE/ROC,ROCL,SVM,P,PC,PLOG,PO*,PCO*,IAV*,IK*,ISAT*,AAV*,AAH

* parameters marked by an asterisk are not needed in this subroutine

Description of Parameters

U	-	input vector of dissipated pore water pressures with (MYE*IEND) elements
SETTL	-	resulting vector of settlements
IEND	-	number of elements of SETTL
KKK	-	number of points in the upper layer in the vertical direction
MYE	-	total number of points in the vertical direction
F	-	multiplying factor; if F=1.0, the consolidation settlements are computed; if F=1/B, where B is Skempton´s pore pressure parameter, total set tlements are computed
FUP	-	parameter for the upper layer; contains the soil parameters
FLO	-	parameter for the lower layer; contains the soil parameters
KIAV=1	-	a constant coefficient of compressibility is used
KIAV=2	-	a variable coefficient of compressibility is used
ROC	-	ratio between the recompression and the virgin compression indices for the upper layer
ROCL	-	recompression index of the lower layer divided by the virgin compression index of the lower layer
SVM	-	modified mathematical molecule for integration in the vertical direction with MYE or (MYE+1) elements
P	-	present overburden effective stress at MYE points
PC	-	preconsolidation stresses at MYE points
PLOG	-	natural logarithm of the ratio between the pre-consolidation and the overburden stresses

Method

The computations are performed first for the upper layer; then, the displacements of the lower layer are evaluated by making the same computations with redefined parameters. A lower layer must be considered only if KKK<MYE.

2.24 Subroutine STAB

Purpose

To search automatically for the minimum factor of safety.

Usage

```
CALL STAB(XC,YC,R,XINP,YINP,MINP,MX,MYE,SU,FX,D,DM,YY)
```

Description of Parameters

XC - X-coordinate of the center of the circular slip circle

YC - corresponding Y-coordinate

R - radius of the circular slip surface

XINP - X-coordinates of the points defining the embankment contour

YINP - corresponding Y-coordinates

MINP - number of points (XINP,YINP)

MX - number of equally spaced grid points in horizontal direction

MYE - number of equally spaced grid points in the vertical direction

SU - undrained shear strengths at (MX*MYE) grid points

FX - resulting factor of safety

D - maximum step size to be used in the search procedure

DM - minimum step size to be used in the search procedure

YY - minimum permissible value for YC

Method and Reference

The programmed method embraces two tactical maneuvres, the "exploratory move" and the "pattern move". Starting from the input base point (XC,YC), an exploratory move is made by varying first XC and then YC. If this move is successful, a pattern move is performed, followed again by a pattern move, if it was successful, and by an exploratory move, if it was not successful. This procedure is repeated until the minimum has been detected, whereafter the step size, by which XC and YC are varied, is decreased. When the minimum factor of safety is found by use of the smallest step size, DM, it is checked to determined whether the corresponding slip circle outcrops in front of the toe of the embankment. If it does not, an additional search is started and the smaller of the obtained minimum factors of safety is returned together with the coordinates and the radius of the corresponding arc.

Subroutines Required

VARYR(YC,XC,R,XINP,YINP,MINP,MX,MYE,SU,FS,DMIN,YY)

Remarks

The input data XC and YC are destroyed and replaced by the coordinates of the arc which gives the minimum factor of safety.

The step size is decreased in the subroutine by dividing by 2; it is, thus, possible that the smallest step size used is less than the input value DM.

2.25 Subroutine VARYR

Purpose

To vary the radii of trial arcs which have the same center coordinates and to compute the associated factors of safety.

Usage

CALL VARYR(YC,XC,R,XINP,YINP,MINP,MX,MYE,SU,FS,DMIN,YY)

Block Names

SAPOD/IOUTP*,W*,H,GLOAD*,CLOAD*,NARC*,NRAD;
* parameters marked by an asterisk are not needed in this subroutine

Description of Parameters

YC - Y-coordinate of the center of the circular slip surfaces

XC - corresponding X-coordinate

R - resulting radius of the arc which gives the minimum factor of safety for the center (XC,YC)

XINP - X-coordinate of the points defining the embankment contour

YINP - corresponding Y-coordinates

MX - number of equally spaced grid points in the horizontal direction

MYE - number of equally spaced grid points in the vertical direction

SU - undrained shear strengths at (MX*MYE) grid points

FS - resulting factor of safety

DMIN - minimum step size to be used in the search procedure

YY - minimum permissible value for YC

H - thickness of the soft soil layer

NRAD - number of trial radii to be used at the input center (XC,YC)

Method and References

After determination of the maximum and minimum possible radii, RMAX and RMIN, respectively, the factors of safety are computed for NRAD radii R=RMAX-I* (RMAX-RMIN)/(NRAD-1). The minimum value of the so-obtained NRAD factors of safety is returned to the calling program.

Subroutines Required

DETFS(XC,YC,R,XINP,YINP,MINP,MX,MYE,SU,FS)

3. Input Data

The main program is written in a interactive manner so that the user will be able to input the following data.

1. Name of the input file (length limited to 50 spaces)

2. Name of the output file (length limited to 50 spaces)

3. Number of symbols to be used in the output graph after execution

4. The characters that are used in the output graph after execution

On execution of the program the following messages will appear on the screen one by one and the user should input the corresponding data.

1. Specify the name of the input file

2. Specify the name of the output file

3. Specify the number of symbols to be used (usually 4)

4. Specify the characters - blank, star, grid, symb(I) I=1, mmm

After specifying these data, the program will use the data on the specified input file and write the results on the specified output file.

Proposed characters are:

Blank	- a blank space
Star	- *
Grid	- I
Symb(1) = U	- for avg. degree of consolidation as a percentage of reference load
Symb(2) = C	- consolidation settlement as a percentage of that of reference load
Symb(3) = O	- immediate settlement as a percent of that of reference load
Symb(4) = T	- total settlement as a percent of that of reference load

(See sample problems for the proper use of these)

This section illustrates the sequence of input data in the main program. A free format style is used. These input data must be given in an input file (the name of the input file is specified by the user).

(a) <u>Input data corresponding to the mesh-generation for the numerical solution, in the compressible layer and type of analysis required</u>.

1. MYE,MHE,ISP,HF,POR,IPOR

MYE - number of equivally spaced points in the vertical direction, including the surface

and the bottom of the compressible layer in the finite difference mesh in the compressible soil MYE ≤ 12

MHE - number of points in the horizontal direction (mesh points) in the compressible soil (MHE ≤ 40)

ISP - identifier where
ISP=0 - settlements, the process of consolidation and the stability are analyzed
ISP=1 - settlements and the process of consolidation are analyzed. Times of load application are required as input parameters

HF - identifier where
HF=0.0 - horizontal flow is neglected in the process of consolidation
HF=1.0 - horizontal flow is not neglected in the process of consolidation

POR - ratio horizontal drainage distance divided by (XT(IEND)*W) in the case of ISP=1, and Set POR=1.0 if this is not known

IPOR - identifier where
IPOR=1 - The user provides the value of POR
IPOR=0 - the user provides POR=1.0 the program will calculate the value of POR

2. JND (add this card only if ISP=0)

JND - number of points in the horizontal direction for which output are required JND ≤ 10

3. (JSP(K),K=1,JND) (add this card only if ISP=0)

JSP(K) - indices of the JND points for which output is required. K=1,JND ≤ 10; the output is for points XE(JSP(K)), where XE are MX equally spaced coordinates between

and including the limits AX(1)˙W and AX(NI)˙W; for example, specification of JSP(1)=1, JSP(JND)=MX causes the output of information at the limits W˙AX(1) and W˙AX(NI) respectively.

4. LND

LND - number of weeks to be plotted on the time axis of the graphical output

5. MX,NI (add this card only if ISP=0)

MX - number of equidistant points in the X-direction between limits AX(I) and AX(NI) MX ≤ 51 User may chose MX as equal to MHE

NI - number of interval limits AX(I); NI ≤ 5

Notes:

AX(NI)˙W is the last point (which is considered in the analysis) in the horizontal direction from the CL. AX(1)=0.0 is the centerline of the embankment.

This horizontal distance between AX(1) and AX(NI) is divided into NI subdivisions. Each subdivision is further divided into MXT points. User may typically use 3-4 subdivisions for each interval between AX(I)˙W and AX(I+1)˙W. (Ref. Krizek and Krugman, 1972 for details.)

6. (AX(I)=1,NI) (add this card only if ISP=0)

AX(I) - sub-interval limits as decimal fractions of reference value W (select values such that a smooth curve along the pore pressure vs. AX(I)˙W will give the expected shape of the pore pressure distribution) (Hint - let contour points of the embankment be some of the AX(I)˙W)

7. (MXT(I),I=1,NI-1 (add this card only if ISP=0)

MXT(I) - number of unequivally spaced points XT between the consecutive limits AX(I) and AX(I+1). I=1, NI-1. Maximum value of MXT(I) ≤ 10. Sum of all MXT(I) ≤ 20

8. IEND (add this card only if ISP=1)

IEND - number of points in the horizontal direction for which output are required

9. (XT(I) I=1,IEND) (add this card only if ISP=1)

XT(I) - X-coordinates of the points at which the settlements and the consolidation behavior are determined
Output are printed for points at distance XT(I)·W

(b) <u>This section gives data corresponding to the compressible layer under the embankment</u>.

10. H,GLOAD,CLOAD,W,YWM,TGPHI

H - thickness of the compressible layer dimension (ft)
If H=0 the program is terminated

GLOAD - unit weight of the embankment soil (pcf)

CLOAD - undrained strength of the embankment soil (psf)

W - reference value in the horizontal direction (ft)

YWM - thickness of a drainage blanket placed on the surface of the compressible soil layer (ft)

TGPHI - tangent of the angle of internal friction of the drainage blanket, if there is one

11. IBCV, LAYER

IBCV - identifier where
IBCV=1 - impeded drainage at Y=H
=2 - free drainage at Y=H
=3 - no drainage at Y=H

LAYER - number which indicates the location of a layer interface; e.g. LAYER=KK means that the layer interface is located at a depth below ground surface which is equal to $Y=\frac{H*(KK-1)}{(MYE-1)}$
If only one type of soil is to be considered SET LAYER=0
4 LE.LAYER.LE.(MYE-3)

12. HI,RKV (add this card only if IBCV=1)

HI - thickness of impedance layer

RKV - ratio of vertical permeabilities

$$\frac{K(\text{drainage soil})}{K(\text{impedance layer})}$$

13. RK,RC,REO,RAV,RCC,ROCL (add this card only if LAYER > 3)

RK - ratio of vertical permeabilities

$$\frac{K(\text{lower soil})}{K(\text{upper soil})}$$

RC - ratio of (vertical) coeff. of consolidation c_v

$$\frac{c_v(\text{lower soil})}{c_v(\text{upper soil})}$$

ROCL - ratio of recompression index of lower soil to that of upper soil

REO - ratio of initial void ratios

$$\frac{e_o(\text{lower soil})}{e_o(\text{upper soil})}$$

RCC - ratio of virgin compression index C_c

$$\frac{c_c(\text{lower soil})}{c_c(\text{upper soil})}$$

RAV - ratio of coefficient of compressibility a_v

$$\frac{a_v(\text{lower soil})}{a_v(\text{upper soil})}$$

14. IVAR,IAV,ICV

All these are identifiers where

IVAR=0 - use constant coeff. of consolidation

IVAR=1 - use variable coeff. of consolidation which are obtained either by interpolation between CHIN(I) and CVIN(I) or by varying the coeff. of compressibility and/or the coefficient of permeability (i.e., if ICV > 0)

IAV=0 - use a constant coeff. of compressibility in the settlement computations

IAV=1 - use the compression indices in the settlement computations

ICV - number of data pairs [PCV(I),CVIN(I)] and [PCH(I),CHIN(I)] through which

Lagrangean/Linear interpolation
polynomials are passed
0 < ICV < 0

15. EO, A

EO - initial void ratio of the upper soil

A - Skempton's pore pressure coefficient (A)

16. AVO (add this card only if IAV=0)

AVO - constant coeff. of compressibility to be used in the settlement computations; in the case of two layers AVO applies to the upper layer (ft^2/lb)

17. CC,ROC,GAMMA (add this card only if IAV=1)

CC - virgin compression index (in the case of two layers this applies to the upper layer)

ROC - ratio of recompression index to the virgin compression index (in the case of two layers - upper layer)

GAMMA - effective unit weight of the subsoil, constant over the thickness of the compressible layer
If GAMMA=0, input of MYE effective overburden stress at equivally spaced depths must be input (pcf)

18. P(I), PC(I) (add this card only if GAMMA=0) (total of MYE cards)

P(I) - present overburden effective stress at MYE equally spaced depths, including the surface MYE ≤ 12 (psf)

PC(I) - preconsolidation stresses at MYE equally spaced depths, including surface, MYE ≤ 12 (psf)

19. CV, CH (add this card only if IVAR=0 and ICV=0)

CV - constant coeff. of consolidation in the vertical direction (in the case of two layer-upper layer) (ft^2/day)

CH - constant coeff. of consolidation in the horizontal direction (in the case of two layers-upper layer) (ft^2/day)

20. PCV(I),CVIN(I),PHC(I),CHIN(I) (add this card only if IVAR=1 and ICV>0) (ICV number of cards)

PCV(I) - effective stresses at which the vertical coeff. of consolidation CVIN(I) are defined ICV ≤ 10 (psf)

PCH(I) - effective stresses at which the horizontal coeff. of consolidation CHIN(I) are defined (psf) ICV ≤ 10

CVIN(I) - variable coefficients of consolidation in the vertical direction (interpolation is done in subroutine coef) (ft^2/day) ICV ≤ 10

CHIN(I) - variable coeff. of consolidation in the horizontal direction (interpolation is done in subroutine coef) (ft^2/day) (ICV ≤ 10)

21. KVO,KHO (add this card only if IVAR=1 and ICV=0)

KVO - initial coeff. of permeability in the horizontal direction

KHO - initial coeff. of permeability in the vertical direction (ft/day)

22. ISAT,IK (add this card only if IVAR=1 and ICV > 0)

These are identifiers where

ISAT=0 - complete saturation

=1 - partial saturation; requires Skempton's pore pressure parameter B < 1.0

IK=0 - constant coefficient of permeability

=1 - horizontal and vertical permeabilities are variables; void ratio vs. the logarithm of the coeff. of permeability is a straight line

23. S,PU,HC,B (add this card only if IVAR=1,ICV > 0 and ISAT=1)

S - degree of saturation to be input as a decimal fraction < 1.0

PU - initial pore gas pressure, if PU is not defined during input, it is set equal to the sum of the atmosphere pressure plus one half the thickness of the compressible layer times the unit weight of water (psf)

HC - Henry's constant of gas solubility, HC=0.020 for atmospheric air, HC=0,029 for methane, HC=2.84 for hydrogen sulfide (at 68^{o}F)

B - Skempton's pore pressure coefficient (B)

24. SKV,SKH (add this card only if IVAR=1,ICV>0,IK=1)

SKV - slope of the void ratio vs. logarithm of vertical coeff. of permeability

SKH - slope of the void ratio vs. logarithm of horizontal coeff. of permeability

25. NC (add this card only if ISP=0)

NC - number of initial undrained shear strengths, CO(I), and $(c/\overline{p})$-ratios,CP(I); NC $\leq$ MYE $\leq$ 12

26. Y UA(I), UB(I) (add this card only if ISP=0) (total of NC cards)

Y - vertical distance below the ground surface at which the initial shear strengths are given (positive downwards) (ft)

UA(I) - initial undrained shear strength CO(I) at depth Y (psf)

UB(I) - $(c/\overline{p})$-ratio at depth Y

* At this point the program will write the data on the OUTPUTFILE.

(c) <u>Following data corresponds to the REFERENCE LOAD</u>.

27. MINP,NS

MINP - the number of points where the coordinates of the embankment will be given. This defines the contour of the embankment (MINP $\leq$ 20)

NS - number of load strips to approximate the actual embankment load (NS $\leq$ 20)

28. XINP(I), YINP(I) (tota of MINP cards)

XINP(I) - X-coordinates of the points defining the embankment contour (ft) (MINP $\leq$ 20)

YINP(I) - Y-coordinates of the points defining the embankment contour (ft) (MINP $\leq$ 20)

(d) Following data corresponds to the load application (i.e. each step of load to the embankment).

29. NL,(IDEN(I),I=1,NL)

NL - number of load strips (NL $\leq$ 6)

IDEN(I) - identifier corresponding to the Ith load strip; where

- IDEN(I) $<$ 0 - the excess pore pressure due to the first load step are equal to the input residual pore pressure
- IDEN(I) = 0 - the excess pore water pressure due to the Ith load are computed by means of subroutine PORE
- IDEN(I) = 1 - the excess pore pressure due to the Ith load are set equal to those computed for the reference load. Note, that this requires that Skempton's coefficients A and B are identical in both cases
- IDEN(I) $<$ 0 - allows the check of an existing installation for which the excess pore pressures just after load application are known from field measurements

30. (TL(I),I=1,NL) (add this card only if ISP=1)

TL(I) - times of load application (i.e. each step of load) in case where ISP=1 NL < 6 (days)

31. FSI,SPEC(1),SPECU(1),TA,DMAX,DMIN,XC,YC,ZZ (add this card only if ISP=0)

FSI - factor of safety required at the time of application of the first load

SPECS(1) - specified fraction of the consolidation settlement due to the reference load. This settlement must have occurred before a new load is applied.

SPECU(1) - when the non-dissipated average pore pressures become less than 5% of the total average pore pressure just after the application of the last load at IEND*SPECU points XT the subsequent loads are disregarded SPEC is a decimal fraction. IEND is the total number of points in the X-direction created by the program (see Sec. 2.1)

TA - available construction time. This is the time at which the final load must have been applied (days)

DMAX - maximum step size to be used in the variation of XC and YC in the search procedure for the minimum factor of safety (ft)

DMIN - minimum step size to be used in the variation of XC and YC in the search procedure for the minimum factor of safety (ft)

XC - X-coordinate of the center of the <u>first trial arc</u>, If XC=0 is input, the program selects a starting value (ft)

YC - Y-coordinate of the center of the <u>first trial arc</u>, IF YC=0 is input, the program selects a starting value (ft) (<u>Note</u> - positive upward)

32. NARC,NRAD (add this card only if ISP=0)

NARC - one-half the number of subarcs within the subsoil to be used in subroutine DETFS; NARC > 1

NRAD - number of trial arcs to be used with each trial center (XC,YC) in the stability analysis; NRAD > 1

33. MINP,NS,IAB (gives data corresponding to the first load)

MINP - same as defined earlier - corresponding to the first load

NS - same as defined earlier - corresponding to the first load

IAB - identifier where

- IAB=0 - Skempton's pore pressure coefficients A and B as defined for the last load are also used to compute the pore pressures due to the load addition
- IAB=1 - redefine A and B (i.e. assign new values for A and B)

34. XINP(I),YINP(I) (total of MINP cards)

XINP(I) - as defined earlier - corresponding to the first load

YINP(I) - as defined earlier - corresponding to the first load

35. A,B (add this card only if IBA=1)

A,B - corresponding Skempton's pore pressure parameters (new)

At this point of the program, if satisfactory FS is not reached, within the available construction time, for the first load the program is terminated (i.e., no loads can be added to the existing embankment). Note - this is for ISP=0

(e) The following data refers to the residual pore pressures under the embankment.

36. IRP

IRP - identifier where
IRP=0 - no residual pore pressures are input
IRP=1 - residual pore pressure at points (W•XT, H•YE) are input columnwise
IRP=2 - residual pore pressure at arbitrary points are input

37. (UC(I),I=1,ISUM) (add this card only if IRP=1)

UC(I) - residual pore pressures under the embankment at points (WcodtXT, H•YE) are input columnwise (psf)

38. X,Y,UA(I),COUNT (add this card only if IRP=2) (number of cards depends on number of arbitrary pore pressures to be given)

X - the X-coordinate at which residual pore pressure UA(I) is specified

Y - the Y-coordinate at which residual pore pressure UA(I) is specified

COUNT - identifier where
COUNT=0.0 - in all the cards except the last card
COUNT=1.0 - the last data card on residual pore pressure

At this point of the program, the internal file unit 1 will be rewinded to initiate the recording of the output data. The program calculates the required parameters corresponding to the first load.

* Steps in this section should specify second and following loads for a total of (NL-1) lifts with proper values corresponding to each step of load, i.e. total of NL load applications NL < 6 are allowed.

(f) The following data corresponds to the second and following loads. [This data should cover (NL-1) loading steps.]

39. MINP,NS,IAB (gives data corresponding to the 2nd load step)

MINP
NS   as defined earlier - corresponding to the 2nd
IAB   load step

40. XINP(I),YINP(I) (gives the contour of the embankment for the 2nd or following load steps) (total number of cards = MINP)

XINP(I)   - as defined earlier - corresponding to the
YINP(I)   2nd or following load step

41. A,B (add this card only if IAB=1)

A   - pore pressure parameters
B

42. FSI,SPECS(LL),SPECU(LL),TMIN,XC,YC,ZZ (add this card only if ISP=0)

FSI   - specified required factor of safety for the 2nd load step

SPECS(LL)   - specified fraction of the consolidation settlement due to reference load that must

have occurred before the addition of the next load step

SPECU(LL) - if an average degree of consolidation of 95% due to the LIFT-TH load is obtained at SPECU(LIFT)*IEND points XT without a sufficient factor of safety for the present load (i.e.LLth load) the LIFTth load is taken to be the last load and NL is set at NL=LIFT (i.e. the present load will not be added to the embankment) SPECU is input as a decimal fraction (see Sec. 2.1)

TMIN - time which must have passed after a load application before the first stability is made to determine whether the next load can be applied. (This saves unnecessary computer time in calculating FS before sufficient pore pressure is dissipated.)

XC
YC - as defined previously - corresponding to the
ZZ LLth load

Note: The program can handle analysis of multiple embankments in a single run.

This is done by adding the card No. 10 at the end of the cards for the previous embankment but with replacing H = 99.

This makes the program to goto the beginning of cards. For second or following embankments data cards should be repeated from 1-42 as in the case of first embankment.

To terminate the program at the end of analysis of n^{th} embankment, simply add the card #10 with H = 0 at the end of data cards for the n^{th} embankment.

4. Sample Problems

Two sample problems have been prepared to show some of the features of the computer programs. In the first problem, only a settlement analysis for a specified load history is required, whereas the second problem simulates actual design conditions

using soil data and cross-section from an unpublished report by the STATE OF ILLINOIS, DIVISION OF HIGHWAYS (1967).

4.1 Sample Problem for Settlement Analysis (Sample Problem #1)

In this first problem the load, which includes a surcharge of 5 feet, is applied at time TL(1)=60 days, and the surcharge is removed at time TL(2)=160 days. The geometry is given in Figure 4.1, and the soil parameters, which are assumed to vary during consolidation, are compiled in Table 4.1 and in Figure 4.2. Output of pore water pressures is required at specified points under the embankment. The input sequence for the soil parameters, the geometry, and the load characteristics follows the list of data cards given in Section 3 for program "Modified SAND" with ISP=1, and the contents of the data cards are listed in Table 4.2 in Appendix A.

The computer output has been abridged, where it was repetitive in nature, and is reproduced in Figure 4.3 in Appendix A.

4.2 Sample Design Problem (Sample Problem #2)

The geometry for this problem is depicted in Figure 4.4 together with a summary of the soil conditions deduced from the boring log shown in Figure 4.5 and the consolidation test data of Figure 4.6. To account for the smaller initial void ratio and larger coefficients of consolidation near the ground surface, it was decided to introduce a layer interface at a depth of (H-H′)=5.2 feet, corresponding to LAYER=3.

The design must satisfy the following requirements: (1) No settlements due to primary consolidation must occur after surcharge removal; in addition, some settlements due to secondary compression should be eliminated; (2) the construction time is not to exceed 12 months; and (3) the factor of safety against instability of the embankment-subsoil system must be equal to or greater than 1.15 during construction and 1.25 under the final load.

The input sequence for the soil parameters, the geometry, and the load characteristics follows the input data in Section 3 for program Modified SAND with ISP=0, and the contents of the data cards are listed in Table 4.3 (Appendix A). The final output includes average degrees of consolidation for a point at the center of the embankment and another point close to the embankment toe, and is reproduced in Figure 4.7 (Appendix A).

4.3 Summary and Conclusions

The objectives of this study were (a) to elucidate the practical and theoretical bases for using the controlled rate of construction technique to design a highway embankment underlain by soft ground, and (b) to synthesize presently available procedures in a comprehensive computer program in which special attention is given to the horizontal and vertical drainage, without sand drain installations. An existing program SAND which considers sand drains has been modified for this purpose.

To facilitate the mathematical treatment, the overall problem was conveniently divided into four parts, which deal with (a) the initial increase in excess pore water pressures caused by an increase of the vertical load on the surface of the compressible layer, (b) the process whereby these pore water pressures are dissipated with time, (c) the associated settlements, and (d) the stability of the embankment-foundation system.

Based on the effective stress principle, the stress increases associated with primary consolidation are taken to be equal to the dissipated pore water pressures. The latter are computed by means of Skempton's pore pressure coefficients A and B and a solution for the total stresses due to a symmetric vertical load acting on a linearly elastic layer of finite thickness, which, in turn, is underlain by a rough rigid substratum. The dissipation of excess pore water pressures is evaluated by use of a consolidation theory which accounts for horizontal and vertical drainage conditions, anisotropic permeability, time-dependent variations of the soil parameters, and partial saturation. As a result of the increases in effective stresses due to the dissipation of pore water pressures, the strength of the subsoil increases, and this is considered in a stability analysis in terms of total stresses by use of the $c/\overline{p}$-ratio.

It is economically possible to establish a number of design charts, which include (a) excess pore pressure distribution curves, (b) consolidation-time curves, (c) stability charts, (d) graphs of maximum embankment height versus thickness of the compressible layer, and (e) relationships for equivalent uniform strength after complete consolidation versus thickness of the subsoil. However, this is beyond the scope of this report.

Since the computational technique used in the "Modified Sand" remains the same as in the original program sand the following remarks are valid.

A. With regard to the computation of the initial excess pore water pressure distribution, the following conclusions can be drawn:

1. The form of the stress equations requires the numerical integration of oscillating integrands, and convergence of the extended Simpson's rule or Filon's formulae with interval halving depends on the geometry of the problem. Poorest convergence was obtained in cases of heavily oscillating integrands when the ratio of the load width to the thickness of the compressible layer was large.

2. When the pore pressure coefficient B is held constant and equal to unity, the influence of the pore pressure coefficient A increases as the thickness of the compressible layer increases, and the average pore water pressures are larger and extend farther in the horizontal direction when A is larger.

3. As the compressible layer becomes thinner relative to the load width, closer agreement is obtained between the applied vertical load and the resulting average pore pressure distribution.

4. The influence of shear stresses causes some concentration of average pore water pressures near the edges of the load.

B. With regard to the computation of primary consolidation settlements, direct proportionality between the average degree of consolidation and the resulting settlement will occur only when constant coefficients of consolidation and a constant coefficient of compressibility are used.

C. With regard to the stability analyses, the following conclusions can be drawn from a critical comparison of the charts in the report (Krizek and Krugman, 1972):

1. Depending on the geometry of the embankment and the soil parameters of the embankment and the subsoil, the assumption of a circular slip surface will give reliable factors of safety only for sufficiently large subsoil thicknesses.

2. The stabilizing influence of flattening the embankment slope decreases as the thickness of the subsoil increases.

3. The slip circle resulting in a minimum factor of safety generally tends to penetrate the soft subsoil as deep as possible.

4. The factor of safety is not proportional to the height of the embankment, but, given identical soil parameters, it depends on the ratio of the embankment height and the thickness of the compressible layer.

Reference

Krizek, R. J. and Krugman, P. K. (1972) "Placement Rates for Highway Embankments", Vol. 1-4, Final Report 1972, Proj. IHR-602, Northwestern University, The Technical Institute, Dept. of Civil Engineering, Evanston, Illinois 60201.

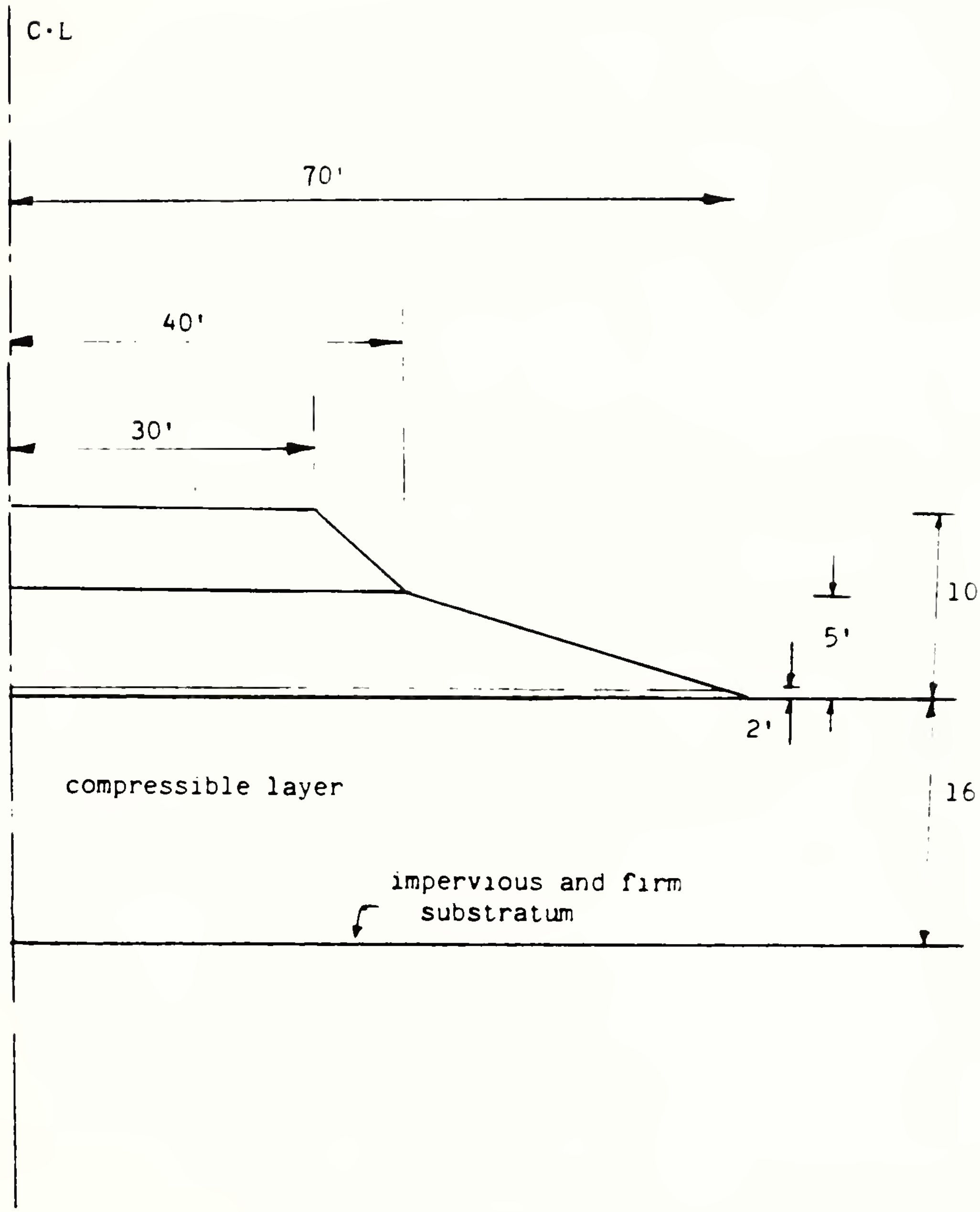


Fig. 4.1 Contour of the Embankment Configuration
for the Sample Problem 1

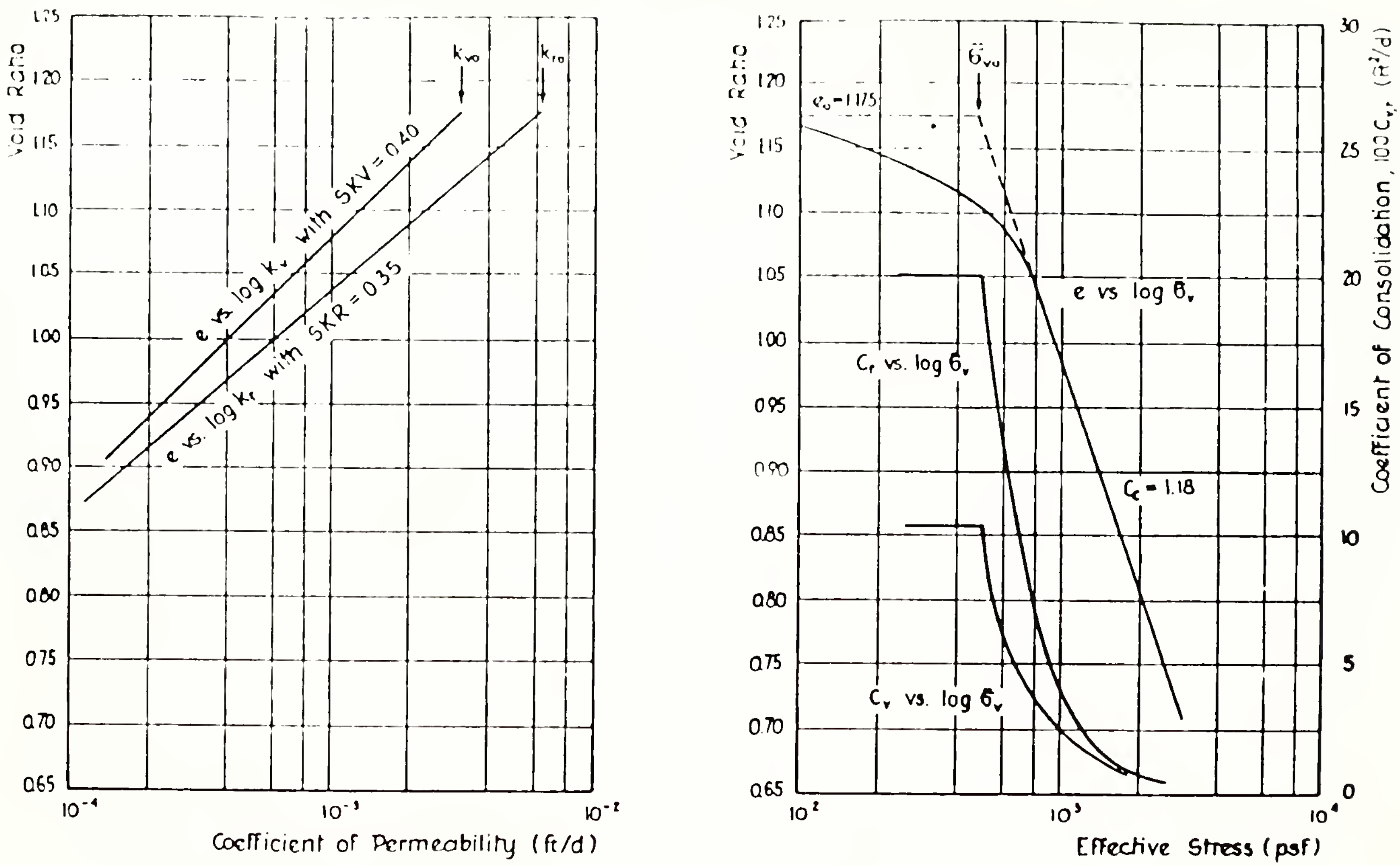


Figure 4.2 Soil Characteristics of a Sample from Depth of 8 ft below Ground

Table 4.1 Soil Data for the First Sample Problem

Soil Parameter	Embankment	Subsoil
Unit weight (pcf)	125	58.8
Initial coefficient of permeability (feet/day)		$K_{HO} = 6.26\text{x}10^{-3}$ $K_{VO} = 3.08\text{x}10^{-3}$
Slope of the void ratio versus log coefficient of permeability curve		SKH = 0.35 SKV = 0.40
Initial void ratio, e_o		1.175
Compression index, C_c		1.18
Skempton's pore pressure coefficients		A = 0.5 B = 0.95
Degree of saturation, S		S = 0.98
Henry's coefficient of gas solubility, HC		0.02

```
11,40,10,1,1.000,1.00,0
40
10
0.0,.1,.2,.3,.4,.5,.7,.9,1.5,1.600
16.0,125.0,1000.,100.,2.0,0.0
3,0
1,1,0
1.175,0.500
1.18,1.0,58.80
.00308,0.00625
1,1
0.98,0.0,0.2,0.95
0.4,0.35
3,5
0.0,5.0
40.0,5.0
70.0,0.0
2,0,1
60.0,160.0
4,10,0
0.0,10.
30.0,10.0
40.0,5.0
70.0,0.0
2
35.0,4.0,75.0,0.0
35.0,15.0,75.0,0.0
105.0,8.5,25.0,1.0
3,5,0
0.0,5.0
40.0,5.0
70.0,0.0
0.0,0.0,0.0,0.0,0.0,0.0
```

Table 4.2 Data Cards for Sample Problem I

```
                 ***********************************
                 *                                 *
                 *       CONSOLIDATION PROBLEM     *
                 *                                 *
                 *      STEP LOADING & SURCHARGE   *
                 ***********************************

Abridged output for Sample Problem 1

THE PORE WATER PRESSURES ARE COMPUTED AT

  YE/H       0.000     0.100     0.200     0.300     0.400
  YE/H       0.500     0.600     0.700     0.800     0.900
  YE/H       1.000

  XT/W       0.000     0.100     0.200     0.300     0.400
  XT/W       0.500     0.700     0.900     1.500     1.600


THE SUBSOIL IS DESCRIBED BY THE FOLLOWING PARAMETERS
WHICH ARE GIVEN FOR THE UPPER LAYER
IN CASE OF STRATIFICATION

TOTAL THICKNESS  H=  16.000  FEET
reference for X-COORD W =  100.000 FEET

SKEMPTON PORE PRESSURE COEFFICIENTS ARE
 A=  0.50 AND B=  0.95

DEGREE OF SATURATION IS S= 0.980
HENRY'S CONSTANT OF GAS SOLUBILITY HC =   0.200
INITL PORE GAS PRESSURE IS PU=   0.2616E+04 PSF

INITIAL VOID RATIO =  1.175

THE COMPRESSION INDEX IS =    0.1180E+01
RECOMPRESSION INDEX/CC   ROC=    1.000
INITIAL EFFECTIVE P AND PRECOMPRESSION
STRESSES PC AS USED IN THE COMPUTATIONS
Y IN FT      P IN PSF     PC IN PSF
    0.000        94.08        94.08
    1.600        94.08        94.08
    3.200       188.16       188.16
    4.800       282.24       282.24
    6.400       376.32       376.32
    8.000       470.40       470.40
    9.600       564.48       564.48
   11.200       658.56       658.56
   12.800       752.64       752.64
   14.400       846.72       846.72
   16.000       940.80       940.80
NOTE -P(1) AND PC(1) MAY HAVE BEEN CHANGED
as compared to input values to avoid over flow

THE INITIAL PERMEABILITIES ARE INVERTICAL DIRn. KVO=    0.3080E-02   FT/DAY
HORIZONTAL DIRN KHO=    0.6250E-02 FT/DAY
THE SLOPES OF THE E Vs LOG(K)-CURVES ARE
     IN VERTICAL DIRN, SKV=     0.400
     IN HORI. DIRN, SKH=      0.350

THE DRAINAGE CONDITIONS ARE
```

```
NO DRAINAGE AT THE BOTTOM


0          REFERENCE LOAD
           **************
           SKEMPTON PORE PRESSURE COEFFICIENTS ARE
            A=  0.50 AND B=  0.95

           THE LOAD CHARACTERISTICS ARE GIVEN BY
           THE UNIT WEIGHT GLOAD=   125.00  PCF
           THE COHESION , CLOAD=   1000.00 PSF
           THICKNESS OF THE DRAINAGE BLANKET YWM=   2.00 FT
           THE TANGENT OF THE ANGLE OF INTERNAL
            FRICTION TGPHI=   0.0000
           MINP=    3 COOR POINTS XINP/YINP
                           0.00 FEET        5.00 FEET
                          40.00 FEET        5.00 FEET
                          70.00 FEET        0.00 FEET
           THE ACTUAL LOAD IS APPROXIMATED BY   5 LOADS
            OF EQ INTENSITY WHICH EXTEND FROM X=0 TO ALPHA(I)
           IF ALPHA(I) IS NEGATIVE, THIS LOAD IS SUBTRACTED

                ALPHA( 1) =      67.000 FEET
                ALPHA( 2) =      61.000 FEET
                ALPHA( 3) =      55.000 FEET
                ALPHA( 4) =      49.000 FEET
                ALPHA( 5) =      43.000 FEET

           THE AVERAGE PORE PRESSURES, UAVER(I)
           THE CONSOLIDATION SETTLEMENTS, SETRC(I) AND
           THE TOTAL SETTLEMENTS,SETRT(I),AT XT(I) ARE
           XT FEET    UAVER (PSF)   SETRC FT.   SETRT FT
              0.00          585.99        3.781        3.896
             10.00          585.24        3.777        3.892
             20.00          581.91        3.761        3.876
             30.00          573.86        3.728        3.842
             40.00          540.09        3.604        3.715
             50.00          401.90        2.975        3.074
             70.00          112.84        1.131        1.180
             90.00           37.77        0.515        0.539
            150.00            2.43        0.037        0.039
            160.00            1.52        0.023        0.024

           THE NUMBER OF LIFTS IS NL=   2

           SINCE ISP=1 TIMES OF LOAD APPLICATION
           ARE INPUT TO BE

           TL( 1)=    60. DAYS
           TL( 2)=   160. DAYS

0          RESIDUAL PORE PRESSURES ARE IN PUT AS
              X (FEET)   Y (FEET)   UC (PSF)
                 35.000       4.000       75.000
                 35.000      15.000       75.000
                105.000       8.500       25.000


0          LOAD NO   1 APPLIED AT TL=    60.DAYS
           *******************************************
```

```
SKEMPTON PORE PRESSURE COEFFICIENTS ARE
 A=  0.50 AND B=  0.95


THE LOAD CHARACTERISTICS ARE GIVEN BY
THE UNIT WEIGHT GLOAD=   125.00  PCF
THE COHESION , CLOAD=   1000.00 PSF
THICKNESS OF THE DRAINAGE BLANKET YWM=   2.00 FT
THE TANGENT OF THE ANGLE OF INTERNAL
 FRICTION TGPHI=   0.0000
MINP=    4 COOR POINTS XINP/YINP
                 0.00 FEET      10.00 FEET
                30.00 FEET      10.00 FEET
                40.00 FEET       5.00 FEET
                70.00 FEET       0.00 FEET

THE ACTUAL LOAD IS APPROXIMATED BY  10 LOADS
 OF EQ INTENSITY WHICH EXTEND FROM X=0 TO ALPHA(I)
IF ALPHA(I) IS NEGATIVE, THIS LOAD IS SUBTRACTED

     ALPHA( 1) =     67.000 FEET
     ALPHA( 2) =     61.000 FEET
     ALPHA( 3) =     55.000 FEET
     ALPHA( 4) =     49.000 FEET
     ALPHA( 5) =     43.000 FEET
     ALPHA( 6) =     39.000 FEET
     ALPHA( 7) =     37.000 FEET
     ALPHA( 8) =     35.000 FEET
     ALPHA( 9) =     33.000 FEET
     ALPHA(10) =     31.000 FEET

T=      0. DAYS X/W    0.000 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW


     0.000
  1217.070
  1220.074
  1223.127
  1226.202
  1229.288
  1232.371
  1235.432
  1238.484
  1241.515
  1244.547


T=      0. DAYS X/W    0.100 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW


     0.000
  1203.986
  1207.619
  1211.390
```

1215.356
1219.585
1224.196
1229.339
1235.257
1242.284
1250.778

T= 0. DAYS X/W 0.200 PORE PRESSURES IN PSF DUE TO VERT + HORI FLC

0.000
1184.936
1185.586
1186.735
1188.883
1192.537
1198.191
1206.311
1217.356
1231.762
1249.895

T= 0. DAYS X/W 0.300 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

0.000
1137.844
1106.615
1088.493
1078.696
1075.409
1077.865
1085.907
1099.824
1120.355
1148.747

T= 0. DAYS X/W 0.400 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

0.000
701.713
735.499
758.469
775.872
790.112
802.631
814.362
825.931
837.748
850.041

T= 0. DAYS X/W 0.500 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

0.000
510.896
519.972
527.333
534.959
542.353
549.100
554.951
559.745
563.326
565.497

T= 0. DAYS X/W 0.700 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

0.000
184.606
198.226
205.020
207.824
207.960
206.043
202.389
197.170
190.481
182.376

T= 0. DAYS X/W 0.900 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

0.000
99.416
96.627
93.800
90.903
87.904
84.783
81.525
78.128
74.598
70.955

T= 0. DAYS X/W 1.500 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

0.000
-3.144
-3.296
-3.459
-3.630
-3.810
-3.996
-4.188
-4.386
-4.588
-4.793

T= 0. DAYS X/W 1.600 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

0.000
-11.767
-11.867
-11.969
-12.077
-12.190
-12.308
-12.430
-12.554
-12.681
-12.811

T= 7. DAYS X/W 0.000 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

0.000
1005.060
1198.883
1221.441
1225.869
1229.022
1232.104
1235.166
1238.208
1241.145
1243.217

T= 7. DAYS X/W 0.100 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

0.000
994.349
1186.681
1209.759
1215.080
1219.404
1224.050
1229.243
1235.208
1242.004
1247.581

T= 7. DAYS X/W 0.200 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

0.000
977.065
1164.192
1184.553
1188.139
1191.965
1197.717
1205.925
1217.008
1230.826
1242.611

T= 7. DAYS X/W 0.300 PORE PRESSURES IN PSF DUE TO VERT + HORI FLO

0.000
927.833
1084.815
1085.476
1076.676
1073.297
1075.710
1083.785
1097.741
1117.368
1135.339

T= 7. DAYS X/W 0.400 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

0.000
577.542
721.089
757.299
776.237
790.899
803.662
815.556
827.204
838.624
846.717

T= 7. DAYS X/W 0.500 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

0.000
414.049
509.569
527.355
535.724
543.083
549.781
555.599
560.358
563.843
565.502

T= 7. DAYS X/W 0.700 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

0.000
150.603
194.164
205.344
208.848
209.181
207.338
203.703
198.499
192.169
187.244

T= 7. DAYS X/W 0.900 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

0.000
78.568
94.598
94.130
91.414
88.405
85.261
81.984
78.583
75.209
72.924

T= 7. DAYS X/W 1.500 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

0.000
-1.739
-2.227
-2.388
-2.511
-2.635
-2.764
-2.896
-3.032
-3.165
-3.253

T= 7. DAYS X/W 1.600 PORE PRESSURES IN PSF DUE TO VERT + HORI FLO

0.000
-9.327
-11.585
-11.964
-12.096
-12.211
-12.329
-12.450
-12.574
-12.695
-12.776

T= 49. DAYS X/W 0.000 PORE PRESSURES IN PSF DUE TO VERT + HORI FLO

0.000
623.692
1002.445
1160.141
1210.504
1224.987
1230.310
1233.690
1236.544
1238.756
1239.663

T= 49. DAYS X/W 0.100 PORE PRESSURES IN PSF DUE TO VERT + HORI FLO

0.000
616.674
992.046
1149.208
1200.274
1216.000
1223.013
1228.602
1234.115
1238.871
1240.950

T= 49. DAYS X/W 0.200 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

0.000
602.520
968.304
1120.361
1169.126
1184.414
1192.669
1201.194
1211.012
1220.169
1224.311

T= 49. DAYS X/W 0.300 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

0.000
555.691
884.480
1011.757
1045.370
1052.045
1056.211
1064.053
1075.741
1087.899
1093.667

T= 49. DAYS X/W 0.400 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

0.000
346.340
585.257
709.914
766.264
793.195
809.690
822.583
833.496
841.602
844.765

T= 49. DAYS X/W 0.500 PORE PRESSURES IN PSF DUE TO VERT + HORI FL

0.000
235.913
401.698
489.368
528.088
545.007
554.048
560.212
564.747
567.677
568.711

T= 49. DAYS X/W 0.700 PORE PRESSURES IN PSF DUE TO VERT + HORI FLO

0.000
86.603
152.094
190.724
208.935
215.348
215.791
213.319
209.699
206.487
205.181

T= 49. DAYS X/W 0.900 PORE PRESSURES IN PSF DUE TO VERT + HORI FLO

0.000
40.089
69.237
84.641
89.974
89.981
87.780
84.901
82.121
80.055
79.277

T= 49. DAYS X/W 1.500 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

```
   0.000
  -1.436
  -2.565
  -3.302
  -3.748
  -4.039
  -4.265
  -4.463
  -4.633
  -4.755
  -4.800
```

T= 56. DAYS X/W 0.000 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

```
    0.000
  594.797
  975.207
 1146.130
 1205.399
 1223.418
 1229.753
 1233.346
 1236.194
 1238.329
 1239.177
```

T= 56. DAYS X/W 0.100 PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW

```
    0.000
  588.056
  965.000
 1135.251
 1195.173
 1214.436
 1222.473
 1228.264
 1233.697
 1238.223
 1240.133
```

T= 56. DAYS X/W 0.200 PORE PRESSURES IN PSF DUE TO VERT + HORI FL

```
    0.000
  574.192
  941.276
 1106.020
 1163.418
 1182.176
 1191.437
 1200.108
 1209.678
 1218.309
 1222.076
```

T= 56. DAYS X/W 0.300 PORE PRESSURES IN PSF DUE TO VERT + HORI FL

```
    0.000
  528.166
  857.962
  997.125
 1038.742
 1048.545
 1053.544
 1061.405
 1072.650
 1083.974
 1089.156
```

Reached end of file

1 THE CONSOL. PROCESS

0 ********************

THE FOLLOWING INFORMATION IS OUT PUT
UAVE(X(1)),UAVE(X(2)),........,
= AVER DEGREES OF CONSOL. WITH RESPECT TP REF. LOAD
SETC(X(1)),SETC(X(2)),......,
= CONSOL. SETTLEMENTS
SETI(X(1)),SETI(X(2)),......,
= IMMMEDIATE SETTLEMENTS
SETT(X(1)),SETT(X(2)),......,
= CONSOLI. + IMMMEDIATE SETTLEMENTS
LAST TWO LINE ARE ONLY OUT PUT
IF SOIL IS PARTIALLY SATURATED (B.NE.1.)
THE POINTS X(I) IN FEET ARE AS FOLLOWS

0.000 10.000 20.000 30.000 40.000 50.000 70.000 90.000150.000160.000

T= 60.
DAYS IS THE TIME OF LOAD APPLICATION

T= 60. DAYS

0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.141	0.141	0.141	0.138	0.124	0.107	0.059	0.030	0.003	0.002
0.141	0.141	0.141	0.138	0.124	0.107	0.059	0.030	0.003	0.002

T= 67. DAYS

0.154	0.153	0.153	0.159	0.090	0.087	0.081	0.156	-0.545	-0.477
1.002	0.997	0.996	1.010	0.746	0.629	0.286	0.196	0.000	0.000
0.141	0.141	0.141	0.138	0.124	0.107	0.059	0.030	0.003	0.002
1.143	1.138	1.137	1.147	0.870	0.736	0.345	0.226	0.003	0.002

T= 74. DAYS

0.185	0.183	0.185	0.196	0.110	0.108	0.098	0.199	-1.572	-0.383
.204	1.197	1.201	1.236	0.919	0.785	0.370	0.254	0.000	0.002
0.141	0.141	0.141	0.138	0.124	0.107	0.059	0.030	0.003	0.002
.345	1.338	1.342	1.373	1.043	0.892	0.429	0.284	0.003	0.004

T= 130. DAYS

.321	0.319	0.329	0.361	0.199	0.198	0.168	0.372	2.614	-0.956
.866	1.857	1.890	1.983	1.459	1.251	0.627	0.430	0.050	0.002
.141	0.141	0.141	0.138	0.124	0.107	0.059	0.030	0.003	0.002
.007	1.998	2.031	2.121	1.583	1.359	0.686	0.460	0.053	0.004

```
0          AVE DEGREE OF CONSOL. AND SETTLEMENT
           CURVES FOR POINT X=     0.00FEET FROM CENTER LINE
           INTERVAL BETWEEN 2 GRID LINES.EQ.10%
           ABSCISSA NUMBERS GIVE THE TIME IN WKS
           THE TOTAL SETTL DUE TO REFERENCE LOAD IS= 0.390E+01FT
0          U -CUREV= AVE. DEGREE OF CONSOL.
           RELATIVE TO THE PORE PRESS DUE TO REF LOAD
0          C -CURVE=CONSOL. SETTL. IN % OF REF. SETTLEMENT
           O -CURVE=IMMEDIATE SETTLEMENTS IN % OF
           THE REFERENCE SETTLEMENTS
           T -CURVE=TOTAL SETTLEMENTS IN % OF
           THE REFERENCE SETTLEMENT
```

Fig. 4.3(a)

```
0  0.0  0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8 0.9  1.0  1.1  1.2  1.3  1.4

   8C*T**I****I****I****I****I****I****I****I****I****I****I****I****I****I
   9* O     U    C T
  10* O      U     C T
  11* O       U      C T
  12* O         U      CT
  13* O         U       C T
  14* O          U       C T
  15* O           U       C T
  16* O            U       CT
  17*
  18* O             U       C T
  19*
  20*
  21*
  22*
  23*
  24*
  25*
  26*
  27*****I****I****I****I****I****I****I****I****I****I****I****I****I****I
1
0          AVE DEGREE OF CONSOL. AND SETTLEMENT
           CURVES FOR POINT X=    10.00FEET FROM CENTER LINE
           INTERVAL BETWEEN 2 GRID LINES.EQ.10%
           ABSCISSA NUMBERS GIVE THE TIME IN WKS
           THE TOTAL SETTL DUE TO REFERENCE LOAD IS= 0.389E+01FT
0          U -CUREV= AVE. DEGREE OF CONSOL.
           RELATIVE TO THE PORE PRESS DUE TO REF LOAD
0          C -CURVE=CONSOL. SETTL. IN % OF REF. SETTLEMENT
           O -CURVE=IMMEDIATE SETTLEMENTS IN % OF
           THE REFERENCE SETTLEMENTS
           T -CURVE=TOTAL SETTLEMENTS IN % OF
           THE REFERENCE SETTLEMENT
```

ig. 4.3(b)

```
0  0.1   0.2   0.3   0.4   0.5   0.6   0.7   0.8  0.9   1.0   1.1   1.2   1.3   1.4   1.5

*T**I****I****I****I****I****I****I****I****I****I****I****I****I****I*****
 O     U    C T                                                           *
 O      U     C T                                                         *
 O       U      C T                                                       *
 O        U       CT                                                      *
 O         U       C T                                                    *
 O          U       C T                                                   *
 O           U       CT                                                   *
 O            U      C T                                                  *
                                                                          *
 O             U       C T                                                *
                                                                          *
                                                                          *
                                                                          *
                                                                          *
                                                                          *
                                                                          *
                                                                          *
                                                                          *
****I****I****I****I****I****I****I****I****I****I****I****I****I****I****I
```

AVE DEGREE OF CONSOL. AND SETTLEMENT
CURVES FOR POINT X=   30.00FEET FROM CENTER LINE
INTERVAL BETWEEN 2 GRID LINES.EQ.10%
ABSCISSA NUMBERS GIVE THE TIME IN WKS
THE TOTAL SETTL DUE TO REFERENCE LOAD IS= 0.384E+01FT
U -CUREV= AVE. DEGREE OF CONSOL.
RELATIVE TO THE PORE PRESS DUE TO REF LOAD
C -CURVE=CONSOL. SETTL. IN % OF REF. SETTLEMENT
O -CURVE=IMMEDIATE SETTLEMENTS IN % OF
THE REFERENCE SETTLEMENTS
T -CURVE=TOTAL SETTLEMENTS IN % OF
THE REFERENCE SETTLEMENT

4.3(c)

```
0  0.1   0.2   0.3   0.4   0.5   0.6   0.7   0.8  0.9   1.0   1.1   1.2   1.3   1.4   1.5

*T**I****I****I****I****I****I****I****I****I****I****I****I****I****I*****
 O     U    C T                                                           *
 O       U     C T                                                        *
 O        U      C T                                                      *
 O          U      C T                                                    *
 O           U      C T                                                   *
 O            U      C T                                                  *
 O             U      C T                                                 *
 O              U      C T                                                *
                                                                          *
 O               U       C T                                              *
                                                                          *
                                                                          *
```

```
 21*
 22*
 23*
 24*
 25*
 26*
 27*****I****I****I****I****I****I****I****I****I****I****I****I****I****I
1
0         AVE DEGREE OF CONSOL. AND SETTLEMENT
          CURVES FOR POINT X=     40.00FEET FROM CENTER LINE
          INTERVAL BETWEEN 2 GRID LINES.EQ.10%
          ABSCISSA NUMBERS GIVE THE TIME IN WKS
          THE TOTAL SETTL DUE TO REFERENCE LOAD IS= 0.372E+01FT
0         U -CUREV= AVE. DEGREE OF CONSOL.
          RELATIVE TO THE PORE PRESS DUE TO REF LOAD
0         C -CURVE=CONSOL. SETTL. IN % OF REF. SETTLEMENT
          O -CURVE=IMMEDIATE SETTLEMENTS IN % OF
          THE REFERENCE SETTLEMENTS
          T -CURVE=TOTAL SETTLEMENTS IN % OF
          THE REFERENCE SETTLEMENT
```

Fig. 4.3(d)

```
0  0.0  0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8 0.9  1.0  1.1  1.2  1.3  1.4

  8C*T**I****I****I****I****I****I****I****I****I****I****I****I****I****I
  9* O  U    C T
 10* O  U      C T
 11* O   U      C T
 12* O    U      C T
 13* O     U      C T
 14* O     U       C T
 15* O      U       CT
 16* O      U       C T
 17*
 18* O       U        CT
 19*
 20*
 21*
 22*
 23*
 24*
 25*
 26*
 27*****I****I****I****I****I****I****I****I****I****I****I****I****I****I
1
0         AVE DEGREE OF CONSOL. AND SETTLEMENT
          CURVES FOR POINT X=     70.00FEET FROM CENTER LINE
          INTERVAL BETWEEN 2 GRID LINES.EQ.10%
          ABSCISSA NUMBERS GIVE THE TIME IN WKS
          THE TOTAL SETTL DUE TO REFERENCE LOAD IS= 0.118E+01FT
0         U -CUREV= AVE. DEGREE OF CONSOL.
          RELATIVE TO THE PORE PRESS DUE TO REF LOAD
0         C -CURVE=CONSOL. SETTL. IN % OF REF. SETTLEMENT
```

O -CURVE=IMMEDIATE SETTLEMENTS IN % OF
THE REFERENCE SETTLEMENTS
T -CURVE=TOTAL SETTLEMENTS IN % OF
THE REFERENCE SETTLEMENT

Fig. 4.3(e)

```
.0   0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8 0.9  1.0  1.1  1.2  1.3  1.4  1.5

C*T**I****I****I****I****I****I****I****I****I****I****I****I****I****I*****
* O U       C  T                                                           *
* O  U           C T                                                       *
* O   U            C  T                                                    *
* O   U              C  T                                                  *
* O    U               C T                                                 *
* O    U                C T                                                *
* O    U                 C T                                               *
* O     U                 C T                                              *
*                                                                          *
* O     U                   C T                                            *
*                                                                          *
*                                                                          *
*                                                                          *
*                                                                          *
*                                                                          *
*                                                                          *
*                                                                          *
*                                                                          *
*****I****I****I****I****I****I****I****I****I****I****I****I****I****I****I
```

AVE DEGREE OF CONSOL. AND SETTLEMENT
CURVES FOR POINT X=   90.00FEET FROM CENTER LINE
INTERVAL BETWEEN 2 GRID LINES.EQ.10%
ABSCISSA NUMBERS GIVE THE TIME IN WKS
THE TOTAL SETTL DUE TO REFERENCE LOAD IS= 0.539E+00FT
U -CUREV= AVE. DEGREE OF CONSOL.
RELATIVE TO THE PORE PRESS DUE TO REF LOAD
C -CURVE=CONSOL. SETTL. IN % OF REF. SETTLEMENT
O -CURVE=IMMEDIATE SETTLEMENTS IN % OF
THE REFERENCE SETTLEMENTS
T -CURVE=TOTAL SETTLEMENTS IN % OF
THE REFERENCE SETTLEMENT

g. 4.3(f)

```
0   0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8 0.9  1.0  1.1  1.2  1.3  1.4  1.5

**T*I****I****I****I****I****I****I****I****I****I****I****I****I****I*****
```

```
 9*  O    U         C  T
10*  O      U             C T
11*  O        U              C  T
12*  O         U                C  T
13*  O          U                  C T
14*  O           U                  C  T
15*  O            U                   C  T
16*  O             U                    C T
17*
18*  O               U                    C  T
19*
20*
21*
22*
23*
24*
25*
26*
27*****I****I****I****I****I****I****I****I****I****I****I****I****I****I*
1
```

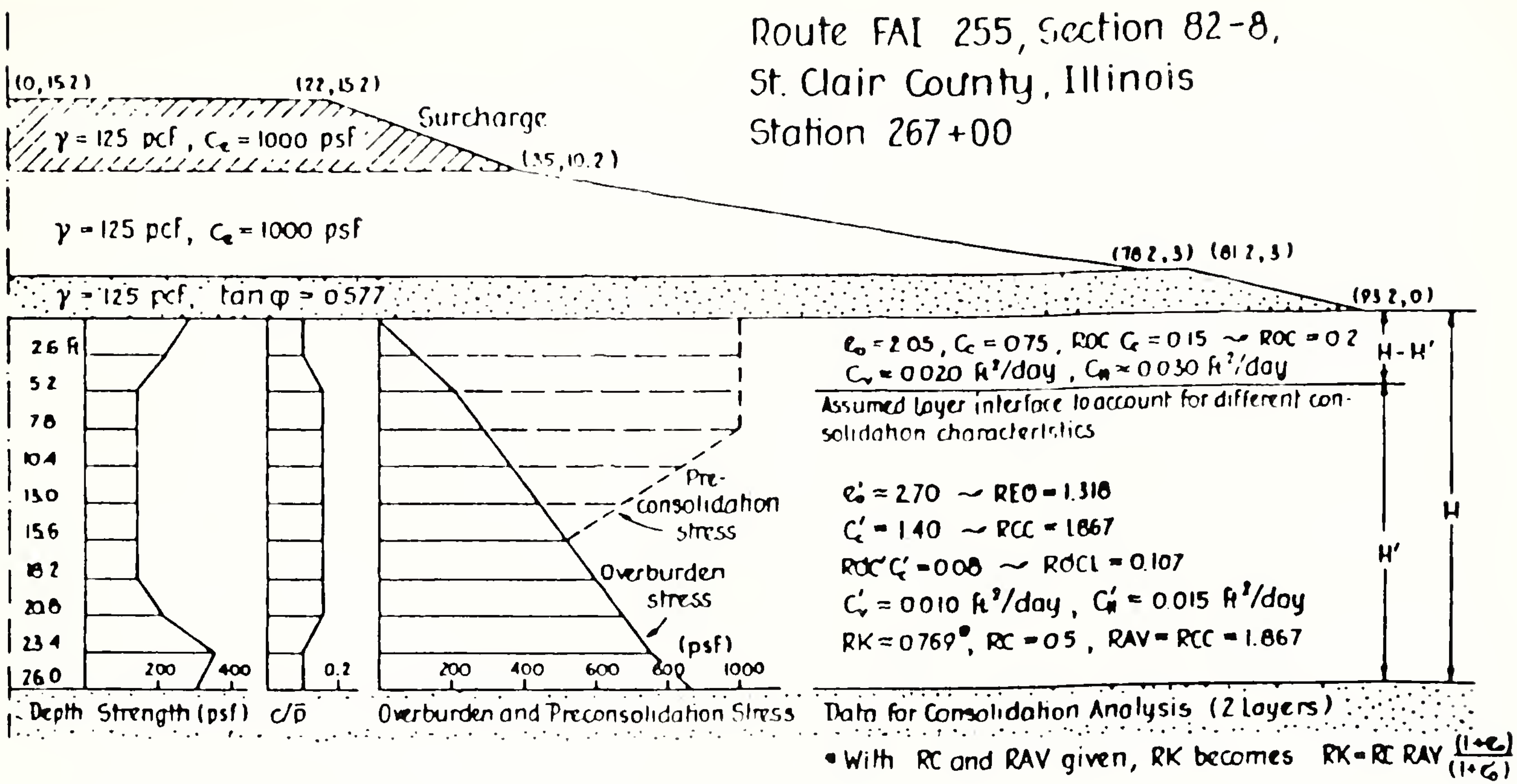


Figure 4.4 Cross-Section and Idealized Soil Condition of the Second Sample Problem

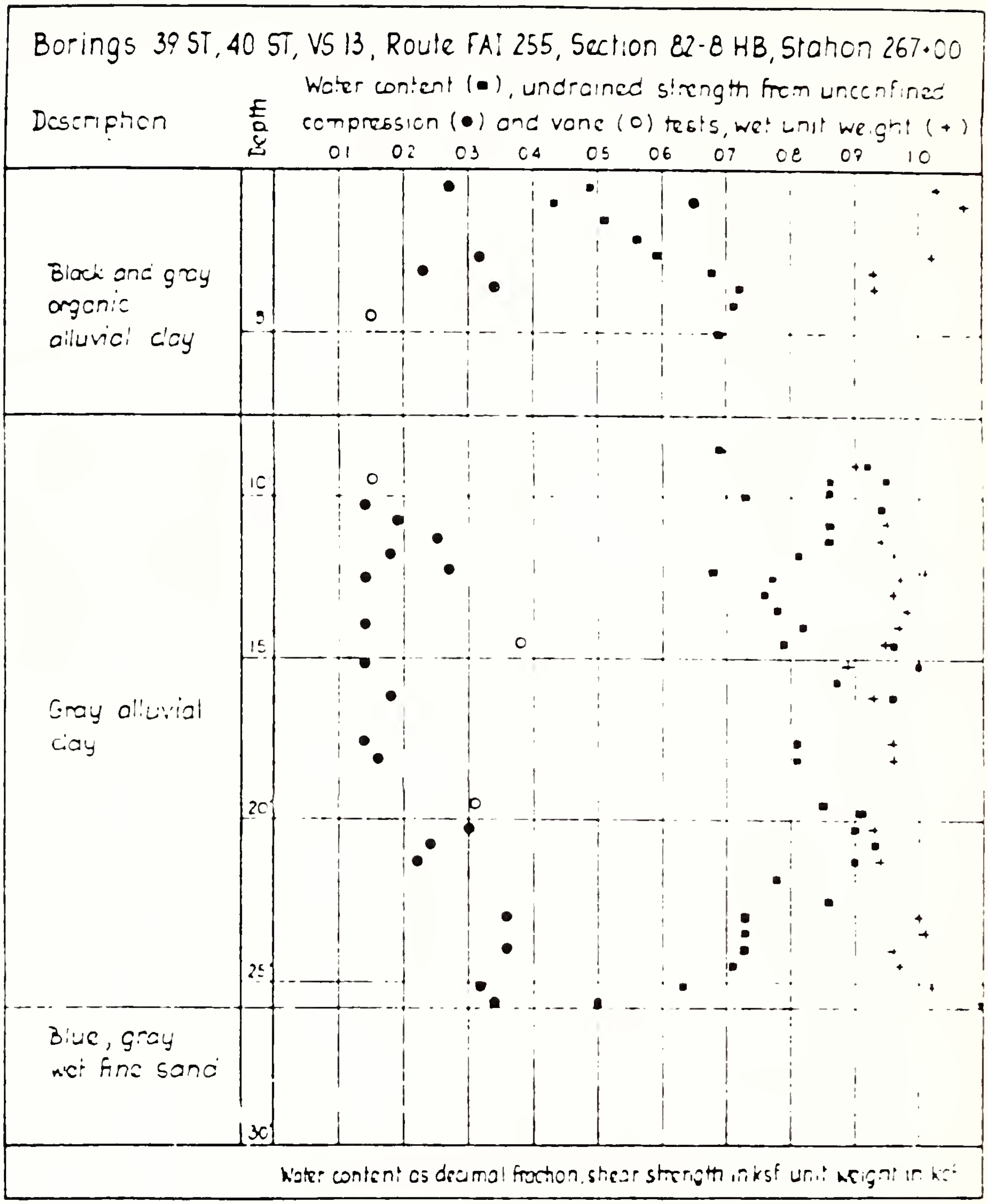


Figure 4.6 Boring Log

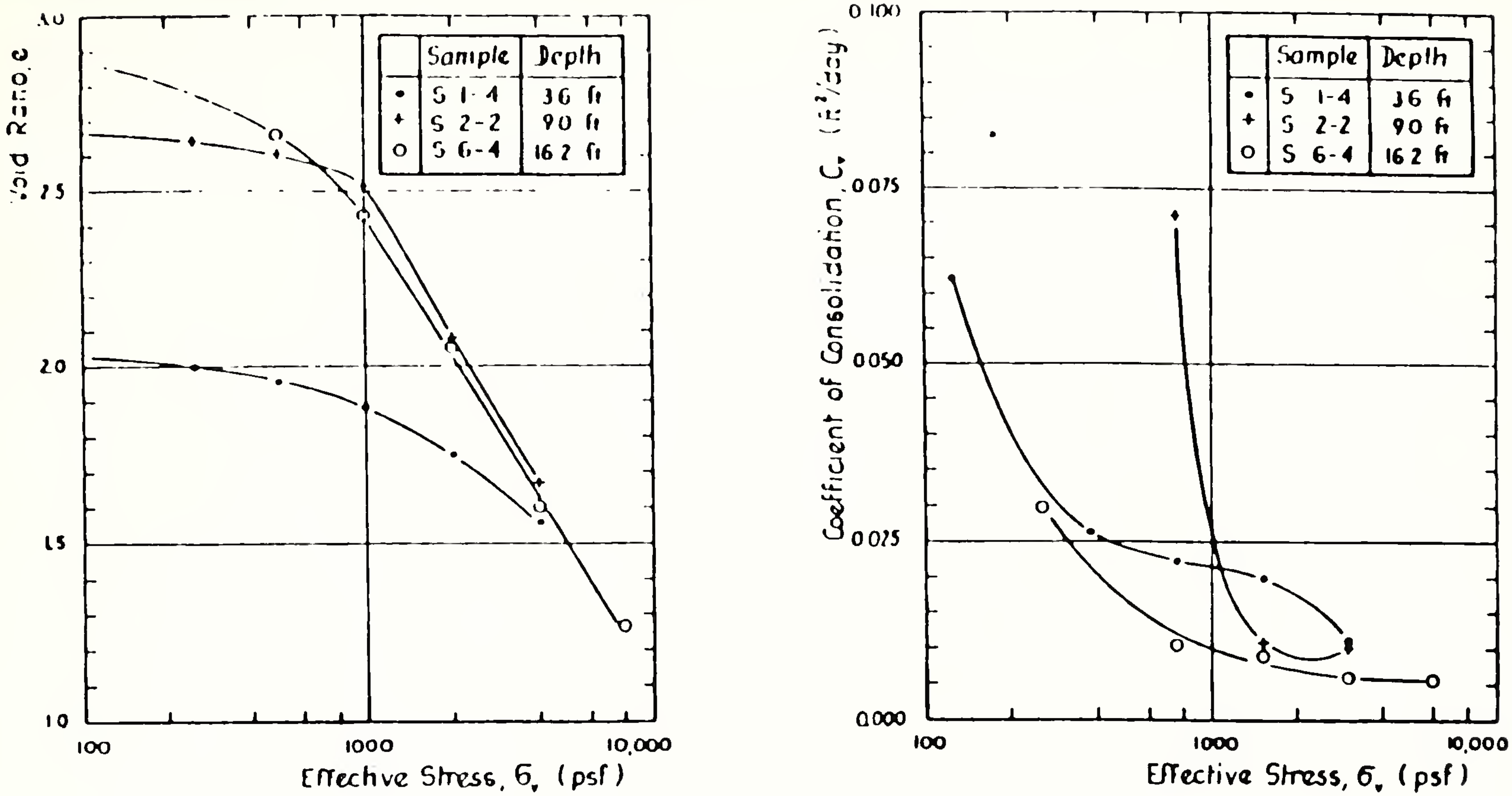


Figure 4.6 Consolidation Test Data

```
11,30,31,0,1.0,1.00,0.0
2
1,9
60
31,5
.0,.3,.65,1.3,3.0
3,5,4,3
26.0,125.,1000.,100.0,3.0,.577
2,4
.769,.5,1.318,1.867,1.867,.107
0,1,0
2.05,.5
.75,.2,.0
0.,1000.
104.,1000.
208.,1000.
286.,1000.
364.,864.
442.,680.
520.,520.
598.,598.
676.,676.
754.,754.
858.,858.
.02,.03
11
0.0,280.,.1
2.6,220.,.1
5.2,150.,.15
7.8,150.,.15
10.4,150.,.15
13.0,150.,.15
15.6,150.,.15
18.2,150.,.15
20.8,210.,.15
23.4,360.,.1
26.0,310.,.1
5,6
0.0,10.2
35.0,10.2
78.2,3.0
81.2,3.0
93.2,0.0
```

Table 4.3 Data Card for Sample Problem 2 (Cont'd on next page)

```
3,1,0,1
1.15,0.00,0.8,360.,4.0,1.0,64.0,40.,0.0
5,6
5,6,0
0.0,10.2
35.0,10.2
78.2,3.0
81.2,3.0
93.2,0.0
0
6,10,0
0.0,15.2
22.,15.2
35.,10.2
78.2,3.0
81.2,3.0
93.2,0.0
1.15,1.2,0.8,0.,57.5,40.,0.
5,6,0
0.0,10.2
35.0,10.2
78.2,3.0
81.2,3.0
93.2,0.0
1.25,0.,0.8,.0,64.,40.,0.
```

```
**********************************
*                                *
*      CONSOLIDATION PROBLEM     *
*                                *
*    STEP LOADING & SURCHARGE    *
**********************************


Abridged output for Sample Problem 2



THE PORE WATER PRESSURES ARE COMPUTED AT

  YE/H        0.000     0.100     0.200     0.300     0.400
  YE/H        0.500     0.600     0.700     0.800     0.900
  YE/H        1.000

  XT/W        0.020     0.150     0.280     0.309     0.372
  XT/W        0.475     0.578     0.641     0.675     0.851
  XT/W        1.099     1.275     1.414     2.150     2.886
THE PORE PRESSURES ARE INTERPOLATED AT

  XE/W=        0.000     0.100     0.200     0.300     0.400
  XE/W=        0.500     0.600     0.700     0.800     0.900
  XE/W=        1.000     1.100     1.200     1.300     1.400
  XE/W=        1.500     1.600     1.700     1.800     1.900
  XE/W=        2.000     2.100     2.200     2.300     2.400
  XE/W=        2.500     2.600     2.700     2.800     2.900
  XE/W=        3.000

ASSUMING COLLOCATION POLYNOMIALS OF DEGREE
2 BETWEEN THE LIMITS      0.000 AND    0.300
4 BETWEEN THE LIMITS      0.300 AND    0.650
3 BETWEEN THE LIMITS      0.650 AND    1.300
2 BETWEEN THE LIMITS      1.300 AND    3.000

THE SUBSOIL IS DESCRIBED BY THE FOLLOWING
PARAMETERS WHICH ARE GIVEN FOR THE UPPER LAYER
IN CASE OF STRATIFICATION

TOTAL THICKNESS  H=  26.000  FEET
reference for X-COORD W =  100.000 FEET

LAYER INTERFACE IS    7.800 FT BELOW SURFACE
LOWER/UPPER PERMEABILITY, RK=    0.769
LOWER/UPPER COEF.OF.CONSOLIDATION,RC=    0.500
LOWER/UPPER INITIAL VOID RATIO, REO=    1.318
LOWER/UPPER COMPRESSION INDEX,RCC=    1.867
LOWER RECOMPRESSION/UPPER RECOMPRESSION-
-INDEX ROCL=    0.107

SKEMPTON PORE PRESSURE COEFFICIENTS ARE
 A=  0.50 AND B=  1.00

INITIAL VOID RATIO =  2.050

THE COMPRESSION INDEX IS =     0.7500E+00
RECOMPRESSION INDEX/CC   ROC=    0.200
```

```
INITIAL EFFECTIVE P AND PRECOMPRESSION
STRESSES PC AS USED IN THE COMPUTATIONS
Y IN FT       P IN PSF     PC IN PSF
    0.000        104.00       1000.00
    2.600        104.00       1000.00
    5.200        208.00       1000.00
    7.800        286.00       1000.00
   10.400        364.00        864.00
   13.000        442.00        680.00
   15.600        520.00        520.00
   18.200        598.00        598.00
   20.800        676.00        676.00
   23.400        754.00        754.00
   26.000        858.00        858.00
NOTE -P(1) AND PC(1) MAY HAVE BEEN CHANGED
as compared to input values to avoid over flow


COEFF CONSOL-VERT FLOW IS CV=   0.2000E-01FT**2/DAY
COEF OF CONSOL-HORI-FLOW IS CH=   0.3000E-01FT**2/DAY

THE DRAINAGE CONDITIONS ARE
FREE DRAINAGE AT THE BOTTOM

THE SHEAR STRENGTH CHARACTERISTICS OF
THE SUB SOIL AS USED IN THE STABILITY ANALYSIS ARE
     DEPTH IN FEET      COHESION IN PSF      P-RATIO
        0.000              280.000                 0.100
        2.600              220.000                 0.100
        5.200              150.000                 0.150
        7.800              150.000                 0.150
       10.400              150.000                 0.150
       13.000              150.000                 0.150
       15.600              150.000                 0.150
       18.200              150.000                 0.150
       20.800              210.000                 0.150
       23.400              360.000                 0.100
       26.000              310.000                 0.100


REFERENCE LOAD
**************

SKEMPTON PORE PRESSURE COEFFICIENTS ARE
 A=  0.50 AND B=  1.00

THE LOAD CHARACTERISTICS ARE GIVEN BY
THE UNIT WEIGHT GLOAD=    125.00  PCF
THE COHESION , CLOAD=   1000.00 PSF
THICKNESS OF THE DRAINAGE BLANKET YWM=   3.00 FT
THE TANGENT OF THE ANGLE OF INTERNAL
 FRICTION TGPHI=   0.5770
MINP=    5 COOR POINTS XINP/YINP
               0.00 FEET      10.20 FEET
              35.00 FEET      10.20 FEET
              78.20 FEET       3.00 FEET
              81.20 FEET       3.00 FEET
              93.20 FEET       0.00 FEET
THE ACTUAL LOAD IS APPROXIMATED BY   6 LOADS
 OF EQ INTENSITY WHICH EXTEND FROM X=0 TO ALPHA(I)
```

```
IF ALPHA(I) IS NEGATIVE, THIS LOAD IS SUBTRACTED

     ALPHA( 1) =      89.800 FEET
     ALPHA( 2) =      82.200 FEET
     ALPHA( 3) =      70.700 FEET
     ALPHA( 4) =      60.500 FEET
     ALPHA( 5) =      50.300 FEET
     ALPHA( 6) =      40.100 FEET

THE AVERAGE PORE PRESSURES, UAVER(I)
THE CONSOLIDATION SETTLEMENTS, SETRC(I) AND
THE TOTAL SETTLEMENTS,SETRT(I),AT XT(I) ARE
XT FEET    UAVER (PSF)   SETRC FT.   SETRT FT
   2.01         1221.99        3.401        3.401
  15.00         1220.05        3.396        3.396
  27.99         1199.55        3.347        3.347
  30.86         1188.66        3.321        3.321
  37.21         1146.45        3.218        3.218
  47.50         1001.05        2.855        2.855
  57.79          831.05        2.403        2.403
  64.14          708.77        2.094        2.094
  67.47          658.25        1.960        1.960
  85.06          361.09        1.175        1.175
 109.94          118.93        0.421        0.421
 127.53           71.97        0.262        0.262
 141.39           49.53        0.187        0.187
 215.00            6.15        0.025        0.025
 288.61            0.76        0.003        0.003


THE NUMBER OF LIFTS IS NL=   3

THE AVAILABLE CONSTRUCTION TIME IS TA=
  360. DAYS. TA IS NOT NEEDED IF NL=1
PARAMETERS USED IN THE STABILITY ANALYSIS
DMAX=    4.000      DMIN=    1.000
NARC=    5NRAD=     6
DMAX, DMIN ARE THE MAX AND MIN STEP SIZES
USED IN THE SEARCH PROCEDURE
NARC=ONE- HALF THE NUMBER OF SUB ARCS
NRAD=NUMBEROF RADII USED FOR EACH TRIAL CENTER
OF ARCS
THE FACTOR OF SAFETY AT TIME T=      0.
DAYS FOR LIFT   1 IS FS=  1.221
AS COMPARED TO THE REQU. FSI=  1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X=   66.00 Y=     41.00 RADIUS=    61.80 IN FT

LOAD NO    1 APPLIED AT TL=      0.DAYS
******************************************
SKEMPTON PORE PRESSURE COEFFICIENTS ARE
 A=  0.50 AND B=  1.00


THE LOAD CHARACTERISTICS ARE GIVEN BY
THE UNIT WEIGHT GLOAD=    125.00  PCF
THE COHESION , CLOAD=   1000.00 PSF
THICKNESS OF THE DRAINAGE BLANKET YWM=   3.00 FT
THE TANGENT OF THE ANGLE OF INTERNAL
```

```
 FRICTION TGPHI=   0.5770
MINP=    5 COOR POINTS XINP/YINP
                0.00 FEET      10.20 FEET
               35.00 FEET      10.20 FEET
               78.20 FEET       3.00 FEET
               81.20 FEET       3.00 FEET
               93.20 FEET       0.00 FEET



THE REQUIRED SAFETY FACTOR IS FSI=  1.150
THE SPECIFIED PORTION OF SETLEMENT IS
EQUAL TO    0.000
 IF 95% OF THE AVE PORE PRESSURE
AT THE TIME OF APPLICATION OF THIS LOAD
HAVE DISSIPATED AT 0.8000*15POINTS XT
THIS LIFT IS ASSUMED TO BE THE LAST ONE

THE FACTOR OF SAFETY AT TIME T=      0.
DAYS FOR LIFT  1WAS .GE.FS=  1.221
AS COMPARED TO THE REQU. FSI=  1.150



THE FACTOR OF SAFETY AT TIME T=      7.
DAYS FOR LIFT   2 IS FS=  1.036
AS COMPARED TO THE REQU. FSI=  1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X=   57.50 Y=    43.00 RADIUS=    62.97 IN FT
THE FACTOR OF SAFETY AT TIME T=     14.
DAYS FOR LIFT   2 IS FS=  1.036
AS COMPARED TO THE REQU. FSI=  1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X=   57.50 Y=    43.00 RADIUS=    62.97 IN FT
THE FACTOR OF SAFETY AT TIME T=     21.
DAYS FOR LIFT   2 IS FS=  1.037
AS COMPARED TO THE REQU. FSI=  1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X=   57.50 Y=    43.00 RADIUS=    62.97 IN FT
THE FACTOR OF SAFETY AT TIME T=     28.
DAYS FOR LIFT   2 IS FS=  1.037
AS COMPARED TO THE REQU. FSI=  1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X=   57.50 Y=    43.00 RADIUS=    62.97 IN FT
THE FACTOR OF SAFETY AT TIME T=     35.
DAYS FOR LIFT   2 IS FS=  1.038
AS COMPARED TO THE REQU. FSI=  1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X=   57.50 Y=    43.00 RADIUS=    62.97 IN FT
THE FACTOR OF SAFETY AT TIME T=     42.
DAYS FOR LIFT   2 IS FS=  1.038
AS COMPARED TO THE REQU. FSI=  1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X=   57.50 Y=    43.00 RADIUS=    62.97 IN FT
THE FACTOR OF SAFETY AT TIME T=     49.
DAYS FOR LIFT   2 IS FS=  1.039
AS COMPARED TO THE REQU. FSI=  1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X=   57.50 Y=    43.00 RADIUS=    62.97 IN FT
THE FACTOR OF SAFETY AT TIME T=     56.
```

```
DAYS FOR LIFT   2 IS FS=  1.039
AS COMPARED TO THE REQU. FSI=  1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X=    57.50 Y=     43.00 RADIUS=     62.97 IN FT
THE FACTOR OF SAFETY AT TIME T=     70.
DAYS FOR LIFT   2 IS FS=  1.040
AS COMPARED TO THE REQU. FSI=  1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X=    57.50 Y=     43.00 RADIUS=     62.97 IN FT
THE FACTOR OF SAFETY AT TIME T=     84.
DAYS FOR LIFT   2 IS FS=  1.041
AS COMPARED TO THE REQU. FSI=  1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X=    57.50 Y=     43.00 RADIUS=     62.97 IN FT
THE FACTOR OF SAFETY AT TIME T=     98.
DAYS FOR LIFT   2 IS FS=  1.042
AS COMPARED TO THE REQU. FSI=  1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X=    57.50 Y=     43.00 RADIUS=     62.97 IN FT
THE FACTOR OF SAFETY AT TIME T=    112.
DAYS FOR LIFT   2 IS FS=  1.043
AS COMPARED TO THE REQU. FSI=  1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X=    57.50 Y=     43.00 RADIUS=     62.97 IN FT
THE FACTOR OF SAFETY AT TIME T=    126.
DAYS FOR LIFT   2 IS FS=  1.044
AS COMPARED TO THE REQU. FSI=  1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X=    57.50 Y=     44.00 RADIUS=     63.42 IN FT
THE FACTOR OF SAFETY AT TIME T=    140.
DAYS FOR LIFT   2 IS FS=  1.045
AS COMPARED TO THE REQU. FSI=  1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X=    57.50 Y=     44.00 RADIUS=     63.42 IN FT
THE FACTOR OF SAFETY AT TIME T=    154.
DAYS FOR LIFT   2 IS FS=  1.046
AS COMPARED TO THE REQU. FSI=  1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X=    57.50 Y=     44.00 RADIUS=     63.42 IN FT
THE FACTOR OF SAFETY AT TIME T=    168.
DAYS FOR LIFT   2 IS FS=  1.047
AS COMPARED TO THE REQU. FSI=  1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X=    57.50 Y=     44.00 RADIUS=     63.42 IN FT
THE FACTOR OF SAFETY AT TIME T=    196.
DAYS FOR LIFT   2 IS FS=  1.048
AS COMPARED TO THE REQU. FSI=  1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X=    57.50 Y=     44.00 RADIUS=     63.42 IN FT
THE FACTOR OF SAFETY AT TIME T=    224.
DAYS FOR LIFT   2 IS FS=  1.050
AS COMPARED TO THE REQU. FSI=  1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X=    57.50 Y=     44.00 RADIUS=     63.42 IN FT
THE FACTOR OF SAFETY AT TIME T=    252.
DAYS FOR LIFT   2 IS FS=  1.052
AS COMPARED TO THE REQU. FSI=  1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X=    57.50 Y=     44.00 RADIUS=     63.42 IN FT
THE FACTOR OF SAFETY AT TIME T=    280.
```

```
DAYS FOR LIFT   2 IS FS=  1.054
AS COMPARED TO THE REQU. FSI=  1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X=   57.50 Y=    44.00 RADIUS=    63.42 IN FT
THE FACTOR OF SAFETY AT TIME T=   308.
DAYS FOR LIFT   2 IS FS=  1.055
AS COMPARED TO THE REQU. FSI=  1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X=   57.50 Y=    44.00 RADIUS=    63.42 IN FT
THE FACTOR OF SAFETY AT TIME T=   336.
DAYS FOR LIFT   2 IS FS=  1.057
AS COMPARED TO THE REQU. FSI=  1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X=   57.50 Y=    44.00 RADIUS=    63.42 IN FT
THE FACTOR OF SAFETY AT TIME T=   364.
DAYS FOR LIFT   2 IS FS=  1.059
AS COMPARED TO THE REQU. FSI=  1.150
FS HAS BEEN OBTAINED FOR THE ARC WITH
X=   57.50 Y=    44.00 RADIUS=    63.42 IN FT


EITHER THE FACTOR OF SAFETY, FS=  1.059
AND/OR THE SETTLEMENT, SETC(1)=  0.751FEET
ARE LESS THAN SPECIFIED AT TIME T=   364.DAYS
WHICH IS GREATER THAN TA=   360.DAYS
*** THIS LIFT NO   1 IS, THEREFORE
CONSIDERED TO BE THE LAST ONE***


     THE CONSOL. PROCESS
     ********************


THE FOLLOWING INFORMATION IS OUT PUT
UAVE(X(1)),UAVE(X(2)),........,
= AVER DEGREES OF CONSOL. WITH RESPECT TP REF. LOAD
SETC(X(1)),SETC(X(2)),.......,
= CONSOL. SETTLEMENTS
SETI(X(1)),SETI(X(2)),.......,
= IMMMEDIATE SETTLEMENTS
SETT(X(1)),SETT(X(2)),.......,
= CONSOLI. + IMMMEDIATE SETTLEMENTS
LAST TWO LINE ARE ONLY OUT PUT
IF SOIL IS PARTIALLY SATURATED (B.NE.1.)
THE POINTS X(I) IN FEET ARE AS FOLLOWS


   0.000 80.000


T=      0.
 DAYS IS THE TIME OF LOAD APPLICATION


T=      0. DAYS
```

0.000 0.000
0.000 0.000

T= 7. DAYS

0.087 0.072
0.361 0.154

T= 14. DAYS

0.091 0.075
0.377 0.160

T= 21. DAYS

0.095 0.078
0.392 0.167

T= 28. DAYS

0.098 0.081
0.405 0.172

T= 35. DAYS

0.102 0.084
0.418 0.178

T= 42. DAYS

0.106 0.087
0.430 0.183

T= 49. DAYS

0.109 0.090
0.441 0.188

T= 56. DAYS

0.112 0.092
0.452 0.193

T= 70. DAYS

.119 0.098
.472 0.202

T= 84. DAYS

.125 0.103
.490 0.210

T= 98. DAYS

.131 0.108
.508 0.219

T= 112. DAYS

.137 0.112
.525 0.226

T= 126. DAYS

143 0.117
541 0.234

T= 140. DAYS

148 0.121
557 0.241

T= 154. DAYS

153 0.125
571 0.248

T= 168. DAYS

159 0.129
586 0.254

T= 196. DAYS

168 0.137

0.613 0.267

T= 224. DAYS

0.177 0.145
0.639 0.278

T= 252. DAYS

0.186 0.152
0.663 0.289

T= 280. DAYS

0.194 0.158
0.686 0.300

T= 308. DAYS

0.202 0.165
0.709 0.310

T= 336. DAYS

0.210 0.171
0.730 0.319

T= 364. DAYS

0.217 0.177
0.751 0.328

T= 392. DAYS

0.224 0.182
0.771 0.337

T= 448. DAYS

0.237 0.193
0.808 0.354

T= 504. DAYS

```
.250  0.203
.844  0.370

     T=   560. DAYS

.262  0.213
.878  0.385

     T=   616. DAYS

.273  0.222
.910  0.399

     T=   672. DAYS

283  0.231
941  0.413

     T=   728. DAYS

293  0.239
970  0.426

     AVE DEGREE OF CONSOL. AND SETTLEMENT
     CURVES FOR POINT X=     0.00FEET FROM CENTER LINE
     INTERVAL BETWEEN 2 GRID LINES.EQ.10%
     ABSCISSA NUMBERS GIVE THE TIME IN WKS
     THE TOTAL SETTL DUE TO REFERENCE LOAD IS= 0.340E+01FT
     U -CUREV= AVE. DEGREE OF CONSOL.
     RELATIVE TO THE PORE PRESS DUE TO REF LOAD
     C -CURVE=CONSOL. SETTL. IN % OF REF. SETTLEMENT


g. 4.7(a)

 0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8 0.9  1.0  1.1  1.2  1.3  1.4  1.5

***I****I****I****I****I****I****I****I****I****I****I****I****I****I*****
  UC                                                                      *
   UC                                                                     *
   UC                                                                     *
   UC                                                                     *
   UC                                                                     *
   UC                                                                     *
   UC                                                                     *
    UC                                                                    *
                                                                          *
    UC                                                                    *
```

```
11*
12*     UC
13*
14*      C
15*
16*      UC
17*
18*      UC
19*
20*      UC
21*
22*       C
23*
24*       UC
25*
26*
27*
28*       UC
29*
30*
31*
32*        C
33*
34*
35*
36*        UC
37*
38*
39*
40*         C
41*
42*
43*
44*         C
45*
46*
47*
48*         UC
49*
50*
51*
52*          C
53*
54*
55*
56*          C
57*
58*
59*
60*****I****I****I****I****I****I****I****I****I****I****I****I****I****I**
```

AVE DEGREE OF CONSOL. AND SETTLEMENT
CURVES FOR POINT X=   80.00FEET FROM CENTER LINE
INTERVAL BETWEEN 2 GRID LINES.EQ.10%
ABSCISSA NUMBERS GIVE THE TIME IN WKS
THE TOTAL SETTL DUE TO REFERENCE LOAD IS= 0.144E+01FT
U -CUREV= AVE. DEGREE OF CONSOL.
RELATIVE TO THE PORE PRESS DUE TO REF LOAD
C -CURVE=CONSOL. SETTL. IN % OF REF. SETTLEMENT

g. 4.7(b)

```
0  0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8 0.9  1.0  1.1  1.2  1.3  1.4  1.5

****I****I****I****I****I****I****I****I****I****I****I****I****I****I*****
   UC                                                                     *
   U C                                                                    *
   U C                                                                    *
   U C                                                                    *
   U C                                                                    *
   U C                                                                    *
   U  C                                                                   *
    U C                                                                   *
                                                                          *
    U C                                                                   *
                                                                          *
    U C                                                                   *
                                                                          *
    U  C                                                                  *
                                                                          *
     U C                                                                  *
                                                                          *
     U C                                                                  *
                                                                          *
     U C                                                                  *
                                                                          *
     U  C                                                                 *
                                                                          *
     U  C                                                                 *
                                                                          *
                                                                          *
                                                                          *
      U C                                                                 *
                                                                          *
                                                                          *
                                                                          *
      U  C                                                                *
                                                                          *
                                                                          *
                                                                          *
       U C                                                                *
                                                                          *
                                                                          *
                                                                          *
       U C                                                                *
                                                                          *
                                                                          *
                                                                          *
       U  C                                                               *
                                                                          *
                                                                          *
                                                                          *
        U C                                                               *
                                                                          *
                                                                          *
                                                                          *
        U C                                                               *
                                                                          *
                                                                          *
```

```
57*
58*
59*
60*****I****I****I****I****I****I****I****I****I****I****I****I****I****I**
```

APPENDIX - A

```
      PROGRAM MSAND
C  FORT1 and FORT2 are internal files.
C  INPUT and OUTPUT files must be specified by the USER.
C
C  ******************************************************************
C
C
C  THIS PROGRAM OPTIMIZES THE RATE AT WHICH A SPECIFIC HIGHWAY
C  EMBANKMENT CAN BE CONSTRUCTED ON SOFT SUBSOIL. THIS PROBLEM
C  INVOLVES THE COMPUTATION OF STRESSES AND PORE PRESSURES IN
C  THE SUBSOIL, THE DISSIPATION OF THESE PORE PRESSURES, THE
C  CORRESPONDING INCREASE IN SHEAR RESISTANCE AND THE STABILITY
C  OF THE EMBANKMENT.
C
C  THE EMBANKMENT LOAD WHICH IS ASSUMED TO ACT VERTICALLY,
C  INDUCES PORE PRESSURES IN THE SUBSOIL WHICH ARE COMPUTED USING
C  THEORY OF ELASTICITY AND SKEMPTON-PORE PRESSURE PARAMETERS
C  A AND B. THESE PORE PRESSURES DISSIPATE ACCORDING TO THREE
C  DIMENSIONAL CONSOLIDATION THEORY WHICH TAKES INTO ACCOUNT
C  THE EFFECT OF GAS AND VARIABLE SOIL PARAMETERS. AS THE PORE
C  WATER PRESSURE DISSIPATES THE EFFECTIVE STRESSES IN THE SUB-
C  SOIL WILL INCREASE GIVING A SIMULTANEOUS INCREASE IN SHEARING
C  RESISTANCE. SETTLEMENTS ARE COMPUTED FROM THE DISSIPATED PORE
C  PRESSURES.
C  *****************************************************************
      Character*50 INPUTFILE,OUTPUTFILE
C
      REAL KVO,KHO
C
      DIMENSION AX(5),JSP(10),MXE(4),MXT(4),MXS(4),OMEGA(40),OMED(40)
      DIMENSION PHI(20),PHID(20),R(510),SETC(20),SETI(20),SETT(20)
      DIMENSION SETRC(20),SETRI(20),SETRT(20),SPECS(10),SPECU(10)
      DIMENSION T(150)
      DIMENSION TB(50),TL(10),UA(220),UB(220),UC(220),UD(220),UAVE(20
      DIMENSION UAVER(20),XE(51),XME(660),XMT(100),XINP(20),XRP(20)
      DIMENSION YE(11),YINP(20),YRP(20),RSP(100),UAVED(20)
      DIMENSION SETR(20),ROW(100),KK(20),SYMB(4),XT(20),SV(11)
      DIMENSION SVM(12),P(11),PC(11),PLOG(11),CO(11)
      DIMENSION CP(11),SU(561),UAVEM(20),UM(220),UU(220),IDEN(10)
      DIMENSION UE(40),UF(40)
C
      EQUIVALENCE (UA(1),XME(1)),(UB(1),XME(221))
      EQUIVALENCE (UC(1),XME(441)),(UD(1),XMT(1))
C
      COMMON/ SAPOD/ IOUTP,W,HH,GLOAD,CLOAD,NARC,NRAD
      COMMON/ SADI1/ LAYER,IBCV,MHE,M,N,IDC,NDR,ISUM,XET(41)
      COMMON/ SADI2/ FIMPV,RC,RK,C,RO,RE,TA,ISP,IVAR
      COMMON/ SACSE/ ROC,ROCL,SVM,P,PC,PLOG,PO,PCO,IAV,IK,ISAT,AAV,AA
      COMMON/ SACO1/ AVOC,KVO,KHO,EOPUS,PU,SKHM,SKVM,CCC,NNN,ICOEF
      COMMON/ SACO2/ PCV(10),CVIN(10),PCH(10),CHIN(10),ICV,KOUNT,HF
      COMMON/ SADET/ XSTAB(51),YSTAB(11),DX,DY,YWM,TGPHI
C
      DATA (TB(I),I=1,45)/
     1  0.,    7.,   14.,   21.,   28.,   35.,   42.,   49.,   56.,
     2 70.,   84.,   98.,  112.,  126.,  140.,  154.,  168.,  196.,
     3 224.,  252.,  280.,  308.,  336.,  364.,  392.,  448.,  504.,
     4 560.,  616.,  672.,  728.,  819.,  910.,1001.,1092.,1274.,
     51456.,1638.,1820.,2184.,2548.,2912.,3276.,3640.,7280./
C
C  Specify the INPUTFILE and OUTPUTFILE Names.
```

```
      INPUT=3
      IOUTP=4
C
       WRITE (*,1132)
1132   FORMAT ('---Specify the Name of your INPUTFILE')
       READ (*,1133)INPUTFILE
       WRITE (*,1134)
1134   FORMAT ('---Specify the Name of the OUTPUTFILE')
       READ (*,1133)OUTPUTFILE
1133   FORMAT (a50)
       OPEN (UNIT=3,FILE=INPUTFILE,STATUS='OLD')
       REWIND (3)
       OPEN (UNIT=4,FILE=OUTPUTFILE,STATUS='NEW',FORM='FORMATTED')
       REWIND (4)
       WRITE (*,1131)
1131   FORMAT ('Specify the No. of Symbols to be used in the plot')
C  The Folowing symbols are proposed for the user to input.
C  Blank = a Blank Space
C  STAR = *
C  GRID = I
C  SYMB (1) = U --For Ave. Deg. of Consolidation.
C  '   '  2  = C --For Consol. Settlement.
C         3  = O --For Imm. '        ' .
C         4  = T --For Total  '      '
        READ (*,*) MMM
        WRITE (*,1130)
1130    FORMAT('Specify Characters-Blank,STAR,GRID,(SYMB(I),1,MMM)')
        READ (*,194)BLANK,STAR,GRID,(SYMB(I),I=1,MMM)
C
C
C  DETERMINATION OF MESH POINTS FOR FINITE DIFFERENCE SCHEME AND
C  STABILITY ANALYSIS.
C  MYE.LE.12,MHE.LE.40: Number of vertical and horizontal points
C  in the finite difference scheme. HF=1.-for horizontal flow
C  POR=Horizontal drainage distance/(XT(IEND)*W).
C  POR-the distance to the zero pore pressure in H dirn from
C  the center line.Put IPOR=1(if POR is input by the user).
C  Put POR=1.0 and IPOR=0 then the program will determine POR
C  ****************************************************************
 999  READ (INPUT,*)MYE,MHE,ITBL,ISP,HF,POR,IPOR
      IF (ITBL.LE.0) ITBL=45
      IF (ITBL.GT.45) ITBL=45
C MMM  Total no. of SYMB (Symbols) to be used in the output
      IF (ISP.EQ.1) GOTO 9001
C Read no. of points for which output is required,if ISP=0.
C If ISP=1 (special points), output the data for points XT.
      read (INPUT,*) JND
      read (INPUT,*) (JSP(K),K=1,JND)
C LND    = No. of lines to be printed.
C (i.e No. of weeks on the time axis in the output)
 9001      continue
      READ (INPUT,*)LND
C
C  GENERATE THE MATHEMATICAL MOLECULE FOR SIMPSONS OR TRAPEZOIDAL
C  RULE IN VERTICAL DIRECTION.
C
      CALL GENS (SV,MYE)
C
C  GENERATE VECTOR YE
C
      MT=MYE-1
```

```
      D=MT
      D=1./D
      DO 11 I=1,MT
      AI=I-1
 11   YE(I)=AI*D
      YE(MYE)=1.
      IF (ISP.EQ.1) GOTO 1
C
C  READ NUMBERS OF EQUIDISTANT POINTS, MX, IN X-DIRECTION, NUMBER
C  OF INTERVALS, NI, AND INTERVAL LIMITS AX(I),I=1,NI.
C  THESE LIMITS ARE DIMENSIONLESS. TO GET THE CORRESPONDING VALUES
C  IN FEET, THE AX(I) ARE MULTIPLIED BY THE REFERENCE VALUE W WHICH
C  IS INPUT LATER.
C
      READ (INPUT,*) MX,NI
      NIM=NI-1
      READ (INPUT,*) (AX(I),I=1,NI)
C
C
C  READ NUMBER OF UNEQUALLY SPACED POINTS IN EACH INTERVAL, MXT(I),
C  GENERATE THE POINTS XT, IF ISP=0
C
      READ (INPUT,*) (MXT(I),I=1,NIM)
      IEND=0
C
C  GENERATE XT-S
C
      DO 21 J=1,NIM
      MT=MXT(J)
      ISTT=IEND+1
      IEND=IEND+MT
      D=2*MT
      AS=AX(J+1)+AX(J)
      AD=AX(J+1)-AX(J)
      DO 22 I=ISTT,IEND
      AI=2*(IEND-I)+1
 22   XT(I)=(AD*COS(AI*3.14159265358979/D)+AS)/2.
 21   CONTINUE
      GOTO 2
C
C
C  READ SPECIAL POINTS IF ISP=1
C  IEND must be atleast 6 and 4 points be directly under the main
C  embankment.
  1   READ (INPUT,*)IEND
      READ (INPUT,*) (XT(I),I=1,IEND)
      GOTO 42
C
C  Generate equidistant points in x-dirn including the limits
C  AX(1)and AX(NI). Determine the number of XE-s in each interval
C  MXE(I). If the left limit of the I-th interval coincides with
C  an XE(K), the limit is considered in MXE(I).
C
 2    MT=1
      J=2
      MM=MX-1
      D=MM
      D=(AX(NI)-AX(1))/D
      XE(1)=AX(1)
      DO 23 I=2,MM
```

```
      XE(I)=XE(I-1)+D
      IF (XE(I).LT.(AX(J)-0.001)) GO TO 23
      MXE(J-1)=I-MT
      MT=I
      J=J+1
 23   CONTINUE
      XE(MX)=AX(NI)
      MXE(J-1)=MX+1-MT
C
C INITIATE THE DETERMINATION OF MATRICES XMT,XME AND R
C
      IEND=0
      JEND=0
      IRND=0
      DO 41 J=1,NIM
C GENERATE MATRIX XMT FROM XT-S AND INVERT XMT
C
      ISTT=IEND+1
      IEND=IEND+MXT(J)
C     PAGE 4
      CALL MATR (ISTT,IEND,MXT(J),XT,AX(J),XMT)
      CALL MINV (XMT,MXT(J),DETER)
C
C  Generate matrix XME from XE-s
C
      JSTT=JEND+1
      JEND=JEND+MXE(J)
      CALL MATR (JSTT,JEND,MXT(J),XE,AX(J),XME)
C Post multiply the inverse of matrix XMT, which is stored in
C array XMT, by matrix XME, and store the result in matrix R
C starting with element R(IRST).
C
      IRST=IRND+1
      IRND=IRND+MXT(J)*MXE(J)
      CALL MPRD (XMT,XME,R,MXT(J),MXT(J),MXE(J),1,1,IRST)
 41   CONTINUE
 42   AIEND=IEND
C
C NOTE THAT THE LAST VALUE OF IEND IS EQUAL TO THE TOTAL
C NUMBER OF XT-S.
C
C
C INPUT DATA FOR A SPECIFIC CASE.
C *****************************************************
C
C Read thickness of soil layer,H,Unit weigeht of the embankment
C load,GLOAD,Undrained strength of the embankment material CLOAD,
C Reference length in H-dirn,W,Thickness of the drainage blanket,
C YWM,Tangent of angle of internal friction,TGPHI.
C If H=0.0 the program is terminated.
C
 100  READ (INPUT,*) H,GLOAD,CLOAD,W,YWM,TGPHI
       IF (H.EQ.0.) GOTO 10000
      IF (H.EQ.99.) GOTO 999
      HH=H
C
C IDC=1 vertical flow only in all XT-s
C IDC=2 vertical + horizontal flow.
C
      IDC=2
```

```
        IF (HF.EQ.0.) IDC=1
C  DETERMINE INCREMENTS IN VERTICAL AND HORIZONTAL DIR
C  -ECTION, DY AND DHX
 45     DY=MYE-1
        DY=H/DY
        DYSQ=DY*DY
C
C Read drainage identifier IBCV
C IBCV=1  Impeded drainage at Y=H,
C IBCV=2  Free drainage at Y=H,
C IBCV=3  No drainage at Y=H
C Read location of interface in case of inhomogeneous soil,
C 4.LE.LAYER.LE.MYE-3
C
        READ (INPUT,*)IBCV,LAYER
        N=MHE-1
        M=MYE-2
        IF (IBCV.EQ.3) M=MYE-1
        IF (IBCV.EQ.2) FIMPV=0.
        IF (IBCV.GT.1) GO TO 4
C
C Read thickness of impedence layer,HI,and ratio of permeabilities,
C RKV=K(draining soil,vertical)/K(impedence layer,vertical)
C
        READ (INPUT,*)HI,RKV
        CHIV=RKV*HI/DY
        FIMPV=CHIV/(1.+CHIV)
 4      IF (HF .EQ. 0.) GO TO 7
C Determine the horizontal grid point to be used in the finite
C difference scheme.
C
        AI=MHE-1
        DHX=POR*XT(IEND)*W/AI
        IAI=AI
        DO 25 I=1,IAI
        XET(I)=POR*(I-1)*XT(IEND)/AI
 25     CONTINUE
        DXSQ=DHX*DHX
C Check for layer interface. Read ratio of permeabilities, RK=
C K(lower)/K(upper), and ratio of coeff. of consolidation,  RC=
C CV(lower)/CV(upper),REO=EO(lower)/EO(upper)=Ratio of initial
C void ratios, RAV=AVO(lower)/AVO(upper)=Ratio of coeff. of
C compress., RCC=(cc(lower layer)/cc(upper layer)=Ratio of
C compression indices. ROCL=cc(recompression,lower)/cc(upper)
C
 7      IF (LAYER .LT. 3) GOTO 6
        READ (INPUT,*)RK,RC,REO,RAV,RCC,ROCL
        IF (LAYER .GT. (MYE-3)) LAYER=0
C
C Read identifiers and parameters for the compressible layer
C IVAR=0 Const. soil parameters in the consolidation process.
C IVAR=1 Variable soil parameter in the consolidation process.
C ISAT=0 100% saturation.
C ISAT=1 Partial saturation.
C IAV=0  Const. coeff. of compressibility.
C IAV=1  Variable coeff. of compressibility.
C ICV=0  Vectors of coeff of coeff of consolidation are not input.
C ICV.GT.0 Vectors of coef. of consol. are input. Variable
C          CV and CH are obtained in subroutine COEFF by
C          interpolation.
```

```
C IK=0   Const. coeff. of permeability.
C IK=1   Variable coeff. of permeability.
C
C EO Initial void ratio.
C KVO Initial vertical permeability.
C KHO Initial horizontal permeability.
C AVO Initial coeff of compressibility.
C A,B Skempton Pore pressure coefficients.
C CC  Compression index of the virgin part of the E Vs LOG(P)
C curve.
C ROC (Recompression index)/CC in case of consolidation.
C GAMMA Buoyant unit weight for computing initial eff. stress.
C P(I)  Initial effective stresses.
C PC(I) Precompression stresses.
C CV,CH Vertical and Horizontal coeff. of consol.
C S     Degree of saturation.
C PU    Initial Gas pressure.
C SKV,SKH Slopes of the void ratio Vs LOG(permeability) curve.
C
 6      READ (INPUT,*) IVAR,IAV,ICV
        IF (ICV .NE. 0) IVAR=1
        READ (INPUT,*) EO,A
        ALPHG=1.
        B=1.
        IF (IAV .EQ. 1) GOTO 350
        READ (INPUT,*) AVO
        GOTO 563
C
C Read cc, ROC and GAMMA. If GAMMA.NE.0., Initial eff stresses,P,
C are computed and normal consol. is assumed. If GAMM=0., initial
C and precompression stresses are input.
C
 350    READ (INPUT,*) CC,ROC,GAMMA
        IF (GAMMA .EQ. 0.) GOTO 561
C
C Initial eff stresses are conputed. PO and PCO are averages
C
        AD=DY*GAMMA
        P(1)=AD
        PC(1)=AD
        PLOG(1)=0.
        PO=GAMMA*H/2.
        PCO=PO
        AI=0.
        DO 565 I=2,MYE
        AI=AI+AD
        P(I)=AI
        PC(I)=AI
        PLOG(I)=0.
  565   CONTINUE
        GO TO 563
C
C Initial eff. and precompression stresses are input.
C
 561    READ (INPUT,*) P(1),PC(1)
        PO=SV(1)*P(1)
        PCO=SV(1)*PC(1)
        DO 562 I=2,MYE
        READ (INPUT,*) P(I),PC(I)
        PO=PO+SV(I)*P(I)
```

```
      PCO=PCO+SV(I)*PC(I)
      PLOG(I)=ALOG(PC(I)/P(I))
 562  CONTINUE
      IF (P(1) .EQ. 0.) P(1)=P(2)
      IF (PC(1) .EQ. 0.) PC(1)=PC(2)
      PLOG(1)=ALOG(PC(1)/P(1))
C If constant parameters are to be used in the cosol. process
C read CV,CH,AVO. If variable parameters are to be used,IF IVAR=1
C read necessary coeffs.
C
563   IF (IVAR .EQ. 1) GOTO 564
      READ (INPUT,*) CV,CH
      GOTO 30
564   IF (ICV .EQ. 0) GOTO  572
      DO 573 I=1,ICV
573   READ (INPUT,*) PCV(I),CVIN(I),PCH(I),CHIN(I)
      GOTO 574
572   READ (INPUT,*) KVO,KHO
574   IF (IAV .EQ. 1) GOTO 566
      AVOC=AVO
      PO=0.
      PCO=0.
566   READ (INPUT,*) ISAT,IK
      IF (ISAT.EQ.0) GOTO 567
      READ (INPUT,*)S,PU,HC,B
      IF (PU.EQ.0.) PU=2117.+62.43*H/2.
      EOPS=EO*PU*(1.-S*(1.-HC))
567   IF (IK.EQ.1) READ (INPUT,*) SKV,SKH
30    CONTINUE
C
C Read NC initial shear strengths CO(I) and C/PBAR-ratios
C at arbitrary depths Y(I). if NC.EQ.MYE, the depths are
C assumed to be equal to H*YE(I). IF NC.LE.MYE the values
C of CO(J) and PC(J) at H*YE(J) are obtained by interpolation.
C The input values are not saved.
C
      IF (ISP.EQ.1) GOTO 585
      READ (INPUT,*)NC
      DO 580 I=1,NC
      READ (INPUT,*) Y,UA(I),UB(I)
580   YRP(I)=Y/H
      IF (NC.EQ.MYE) GOTO 581
      CALL LAGR (YE,CO,MYE,1,YRP,UA,NC)
      CALL LAGR (YE,CP,MYE,1,YRP,UB,NC)
      GOTO 582
581   DO 583 I=1,MYE
      CO(I)=UA(I)
583   CP(I)=UB(I)
C
C Define the vectors XSTAB and YSTAB which are needed in the
C stability analysis.
C
582   DO 584 I=1,MX
584   XSTAB(I)=W*XE(I)
      DX=XSTAB(2)-XSTAB(1)
C
      DO 586 I=1,MYE
586   YSTAB(I)=H*YE(I)
585   CONTINUE
C
```

```
C OUTPUT OF DATA INPUT SO FAR. FOR FORMAT STATEMENTS
C SEE END OF PROGRAM
C ***************************************************
C
        WRITE (IOUTP,901)
        WRITE (IOUTP,900)
        WRITE (IOUTP,903)
        WRITE (IOUTP,900)
        WRITE (IOUTP,904)
        WRITE (IOUTP,902)
        WRITE (IOUTP,905) (YE(I),I=1,MYE)
        WRITE (IOUTP,902)
        WRITE (IOUTP,906) (XT(I),I=1,IEND)
        WRITE (IOUTP,902)
        IF (ISP.EQ.1) GOTO 53
        WRITE (IOUTP,907)
        WRITE (IOUTP,902)
        WRITE (IOUTP,908) (XE(I),I=1,MX)
        WRITE (IOUTP,909)
        DO 51 I=1,NIM
        MM=MXT(I)-1
 51     WRITE (IOUTP,910) MM,AX(I),AX(I+1)
        WRITE (IOUTP,902)
 53     WRITE (IOUTP,901)
        WRITE (IOUTP,902)
        WRITE (IOUTP,913)
        WRITE (IOUTP,914)H,W
        WRITE (IOUTP,902)
        IF (LAYER.LT.3) GOTO 54
        AI=YE(LAYER)*H
        WRITE (IOUTP,915) AI,RK,RC,REO
        IF (IAV. EQ.0) GOTO 551
        WRITE (IOUTP,715)RCC,ROCL
        GOTO 552
 551    WRITE (IOUTP,815) RAV
 552    WRITE (IOUTP,902)
  54    WRITE (IOUTP,916) A,B
         IF ((1.-B).LT.0.00001) GOTO 55
        WRITE (IOUTP,917) S,HC,PU
        WRITE (IOUTP,902)
  55    WRITE (IOUTP,918) EO
        WRITE (IOUTP,902)
        IF (IAV.EQ.1) GO TO 553
        WRITE (IOUTP,818)AVO
        WRITE (IOUTP,902)
        GOTO 554
  553   WRITE (IOUTP,919)CC,ROC
        WRITE (IOUTP,819)
        DO 555 I=1,MYE
        AI=YE(I)*H
        WRITE (IOUTP,719) AI,P(I),PC(I)
  555   CONTINUE
        WRITE (IOUTP,619)
        WRITE (IOUTP,902)
  554   IF (IVAR.EQ.1) GOTO 556
        WRITE (IOUTP,934) CV,CH
        GOTO 57
  556   IF (ICV.EQ.0) GOTO 575
        WRITE (IOUTP,820)
        DO 576 I=1,ICV
```

```
 576    WRITE(IOUTP,720)PCV(I),CVIN(I),PCH(I),CHIN(I)
        GOTO 57
 575    WRITE (IOUTP,920) KVO,KHO
        IF (IK.EQ.1) WRITE (IOUTP,921)SKV,SKH
 57     WRITE (IOUTP,902)
        WRITE (IOUTP,922)
        IF (IBCV.NE.1) GOTO 61
        WRITE (IOUTP,926)HI,RKV
        GOTO 64
 61     IF (IBCV.EQ.3) GOTO 63
        WRITE (IOUTP,927)
        GOTO 64
 63     WRITE (IOUTP,928)
C
 64     WRITE (IOUTP,902)
        IF (ISP.EQ.1) GOTO 587
        WRITE (IOUTP,961)
        DO 588 I=1,MYE
 588    WRITE (IOUTP,962) YSTAB(I),CO(I),CP(I)
 587    WRITE (IOUTP,900)
C
C Define the modified molecules SVM in vertical direction.
C Redefine ROCL to be the ratio of the Recompression index
C of the lower layer and the compression index of the virgin
C part of the lower layer.
C Redefine also the parameters KKK,KIAV,NNN,FUP,FLO,SKVM,SKHM
C CCC,AAV,AAH and ICOEFF, which are needed in subroutines SETL
C and COEFF.
C Redefine also PCV,PCH,CVIN,CHIN in case that ICV.NE.0
C
        AI=1.+EO
        AAV=AI/(62.42796*DYSQ)
        IF (HF.EQ.0.) GOTO 521
        AAH=AI/(62.42796*DXSQ)
 521    KKK=MYE
        KIAV=IAV+1
        NNN=1
        AD=H
        IF (LAYER.GE.3) GOTO 524
        DO 523 I=1,MYE
 523    SVM(I)=SV(I)
        GOTO 522
 524    KKK=LAYER
        CALL GENS(SVM,KKK)
        MM=MYE-LAYER+1
        CALL GENS(UA,MM)
        II=LAYER
        DO 525 I=1,MM
        II=II+1
 525    SVM(II)=UA(I)
        AS=1.+EO*REO
        IF (RCC.NE.0.) ROCL=ROCL/RCC
        AD=H*YE(LAYER)
 522    ICOEF=1
        IF (IK.EQ.1) ICOEF=2+IAV
        IF (ICV.EQ.0) GOTO 530
        ICOEF=4
        DO 529 I=1,ICV
        PCV(I)=ALOG(PCV(I))
        CVIN(I)=CVIN(I)/DYSQ
```

```
      IF (HF.EQ.0.) GOTO 529
      PCH(I)=ALOG(PCH(I))
      CHIN(I)=CHIN(I)/DXSQ
529   CONTINUE
530   IF (IAV.EQ.1) GOTO 527
C
C Coeff. of compressibility is const (IAV=0)
C
      FUP=AD*AVO/AI
      IF (LAYER.GE.3) FLO=(H-AD)*AVO*RAV/AS
      IF (IK.EQ.0) GOTO 520
      SKVM=2.302585*AVO/SKV
      IF (HF.EQ.0.)  GOTO 520
      SKHM=2.302585*AVO/SKH
      GOTO 520
C
C Variable coeff. of compressibility IAV=1.
C
527   CCC=0.4342945*CC
      AVOC=CCC/PCO
      IF (PCO.GT.PO) AVOC=AVOC*(PCO/PO)**ROC
      FUP=AD*CCC/AI
      IF (LAYER.GE.3) FLO=(H-AD)*CCC*RCC/AS
      IF (IK.EQ.0) GOTO 520
      SKVM=CC/SKV
      IF (HF.GT.0.) SKHM=CC/SKH
C
C
C
C  REFERENCE LOAD.
C  ***********************************************************
C
C Read characteristics of the reference load.
C XINP,YINP -the coordinates of the polygon which describes
C the load.
C MINP- The no. of points.
C NS- The no. of strips by which the actual load is approximated.
C
520   READ (INPUT,*)MINP,NS
      WRITE (IOUTP,935)
      WRITE (IOUTP,916) A,B
      WRITE (IOUTP,930) GLOAD,CLOAD,YWM,TGPHI,MINP
      DO 101 I=1,MINP
      READ (INPUT,*) XINP(I),YINP(I)
101   WRITE (IOUTP,931) XINP(I),YINP(I)
C
C Compute the pore water pressures at (XT(I),I=1,IEND)/YE(J),J=1,MYE)
C
C
      CALL PORE (XINP,YINP,MINP,NS,XT,IEND,YE,MYE,UB,A,B)
C  determine the horizontal distance from the Center line to the point
C  where the pore pressure is 0.1% of the max pore pressure under the
C  embankment. This is taken as a free drainage end.
      CALL HDIST (UB,XT,IEND,ICV,CHIN,DXSQ,AAH,MHE,W,XET,IPOR,
     * HF,MYE,POR)
      IPOR=1
C
C
C Compute the average pore pressures UAVER(I),I=1,IEND for the
C reference load. Determine final consolidation settlements,SETREC(I),
```

```
C Immediate settlements,SETRI(I), and Total settlements (SETRT(I),
C I=1,IEND for the reference load.
C
        II=0
        DO 501 I=1,IEND
        UAVER(I)=0.
        DO 102 J=1,MYE
        II=II+1
        UU(II)=UB(II)
 102    UAVER(I)=UAVER(I)+UB(II)*SV(J)
 501    CONTINUE
C
        CALL SETL (UB,SETRC,IEND,KKK,MYE,1.,FUP,FLO,KIAV)
        IF (B.NE.1.) GOTO 513
        DO 514 I=1,IEND
        SETRT(I)=SETRC(I)
 514    SETRI(I)=0.
        GOTO 515
 513    FAC=1./B
        CALL SETL (UB,SETRT,IEND,KKK,MYE,FAC,FUP,FLO,KIAV)
C
C Define initial parameters.
C TL(LIFT) Time of LIFT-th load application.
C TB(ITB)  Time from TL(LIFT) till TL(LIFT+1) given in DATA
C statement.
C Y(IT)    Time from first load application, T(IT)=TL(LIFT)
C +TB(ITB)
C
 515    WRITE (IOUTP,932)
        DO 71 I=1,IEND
        AI=W*XT(I)
        WRITE(IOUTP,933)AI,UAVER(I),SETRC(I),SETRT(I)
 71     CONTINUE
        WRITE (IOUTP,900)
        ISUM=MYE*IEND
        LIFT=1
        LL=LIFT+1
        ITB=1
        IT=1
        TL(1)=0.
        TB(1)=0.
        T(1)=0.
C
C Read no. of lifts,NL. If computation for special points is required
C (ISP=1), read also NL times of load application,TL.
C NLS is defined for checking purposes at the end of the program
C IDEN(1).LT.0, Pore pressures due to the first load are set
C equal zero.
C IDEN(I)=0, , I=1,NL pore pressures due to the I-th load are4
C computed by means of subroutine PORE.
C IDEN(I)=1, I=1,NL POre pressures due to the I-th load are
C set equal to those due to the REFERENCE load.
C
        READ (INPUT,*) NL,(IDEN(I),I=1,NL)
        NLS=NL
        WRITE (IOUTP,936) NL
        WRITE (IOUTP,902)
        IF (ISP.EQ.0) GOTO 103
        READ (INPUT,*) (TL(I),I=1,NL)
        WRITE (IOUTP,937)
```

```
      DO 106 I=1,NL
 106  WRITE (IOUTP,938) I,TL(I)
      WRITE (IOUTP,902)
      T(1)=TL(1)+TB(1)
      GOTO 105
C
C FIRST LOAD.
C *******************************************************
C
C Read characteristics of the first load, also
C TA    Available construction time.
C SPECS Specified settlement for the first lift.
C SPECU When the NOT DISSIPATED average pore pressures
C       become less than 5% of the total average pore pressure
C       at the time of load application at IEND*SPECU points,
C       the subsequent loads are disregarded.
C FSI   Factor of safety for the first lift.
C DMAX  max. interval used in the search for the minimum FS
C DMIN  Corresponding minimum interval.
C ZZ    Distance between the maximum YINP and the minimum
C       permissible YC during the search procedure.
C NARC  One-half the no. of subarcs used in subroutine DETFS
C NRAD  No. of trial arcs used at each center YC,YC
C IAB=0 Use A and B as defined earlier.
C IAB.NE.0 Read new values of A and B.
C
 103  READ (INPUT,*) FSI,SPECS(1),SPECU(1),TA,DMAX,DMIN,XC,YC,ZZ
      READ (INPUT,*) NARC,NRAD
      IF (DMAX.GT.DMIN) GOTO 401
      DMAX=H/2.
      DMIN=H/20.
 401  WRITE (IOUTP,940) TA
      WRITE (IOUTP,840) DMAX,DMIN,NARC,NRAD
 105  READ (INPUT,*) MINP,NS,IAB
      DO 506 I=1,MINP
 506  READ (INPUT,*)XINP(I),YINP(I)
      IF (IAB.NE.0) READ (INPUT,*) A,B
      IF (ISP.EQ.1) GOTO 107
C
C CALL SUBROUTINES FOR STABILITY ANALYSIS
C
      CALL INIT (XINP,YINP,MINP,XC,YC,YY,ZZ,DMIN)
      CALL GAIN (UA,R,SU,MYE,MXT,MXE,MX,NIM,CO,CP,1)
      CALL STAB (XC,YC,RR,XINP,YINP,MINP,MX,MYE,SU,FS,DMAX,DMIN,YY)
      DO 570 I=1,ISUM
 570  UA(I)=0.
C
      WRITE (IOUTP,942) T(IT),LIFT,FS,FSI
      WRITE (IOUTP,842) XC,YC,RR
      IF (FS.GE.FSI) GOTO 107
      WRITE (IOUTP,943)
C
C Since Branching to the input of a new case might result in the
C reading of the following load characteristics instead of the
C data for a new run, the program is terminated here.
C
     GOTO 10000
 107    WRITE (IOUTP,902)
C
C RESIDUAL PORE PRESSURES
```

```
C *****************************************************************
C
C Read index IRP and, for IRP.NE.0 residual pore pressures.
C
C IRP=0  No residual pore pressures.
C IRP=1  Residual pore pressures at XT/YE are input.
C IRP=2  Residual pore pressures at points other than XY/YE
C are input.
C
        READ (INPUT,*) IRP
        IF (IRP-1) 109,110,111
C
C NO RESIDUAL PORE PRESSURES
C
 109    DO 112 J=1,ISUM
 112    UC(J)=0.
        GO TO 108
C
C Residual pore pressures at points XT/YE. Input is columnwise
C with each input card containing ten values
C
 110    READ (INPUT,*) (UC(I),I=1,ISUM)
        WRITE (IOUTP,944) (YE(J),J=1,MYE)
        II=1-MYE
        IJ=0
        DO 113 I=1,IEND
        II=II+MYE
        IJ=IJ+MYE
 113    WRITE (IOUTP,945) I,XT(I),(UC(J),J=II,IJ)
        GOTO 108
C
C Residual pore pressures at points other than XT/YE. Residual
C pore pressures at XT/YE are obtained by interpolation. The
C input values are not saved.
C
 111    WRITE (IOUTP,946)
        I=1
        J=1
        READ (INPUT,*) X,Y,UA(1),COUNT
        WRITE (IOUTP,947) X,Y,UA(1)
        XRP(1)=X/W
        YRP(1)=Y/H
        IF (COUNT.EQ.0.) GOTO 115
        DO 114 J=1,ISUM
 114    UC(J)=UA(1)
        GO TO 108
 115    READ (INPUT,*) X,Y,U,COUNT
        WRITE (IOUTP,947) X,Y,U
        X=X/W
        Y=Y/H
          IF (ABS(X-XRP(I)).LT.0.00001) GOTO 116
        IJ=(I-1)*MYE+1
C
C
        CALL LAGR (YE,UC,MYE,IJ,YRP,UA,J)
        I=I+1
        XRP(I)=X
        J=0
 116    J=J+1
        YRP(J)=Y
```

```
      UA(J)=U
      IF (COUNT.EQ.0.) GO TO 115
      IJ=(I-1)*MYE+1
      CALL LAGR (YE,UC,MYE,IJ,YRP,UA,J)
      IJ=1-IEND
      DO 117 JJ=1,MYE
      II=JJ-MYE
      IJ=IJ+IEND
      DO 118 J=1,I
      II=II+MYE
118   UA(J)=UC(II)
117   CALL LAGR (XT,UD,IEND,IJ,XRP,UA,I)
      IJ=0
      DO 119 JJ=1,IEND
      II=JJ-IEND
      DO 119 J=1,MYE
      IJ=IJ+1
      II=II+IEND
      UC(IJ)=UD(II)
119   CONTINUE
C
C Write load characteristics and compute average pore pressure and
C immediate settlements. rewind tape 1 fore storage purposes.
C
108   REWIND 1
C
      WRITE (IOUTP,900)
      WRITE (IOUTP,939) LIFT,TL(LIFT)
      WRITE (IOUTP,916) A,B
      WRITE (IOUTP,930) GLOAD,CLOAD,YWM,TGPHI,MINP
      DO 120 I=1,MINP
120   WRITE (IOUTP,931) XINP(I),YINP(I)
      WRITE (IOUTP,902)
C
      IF (IDEN(1)) 73,74,516
74    IDEN(1)=MINP
73    CALL PORE (XINP,YINP,IDEN(1),NS,XT,IEND,YE,MYE,UB,A,B)
      IF (HF.EQ.0.) GOTO 516
      IF (IPOR.EQ.1) GOTO 516
C
C Find the horizontal distance to the point where the pore pressure is
C 0.1% of the maximum pore pressure under the embankment. This is
C considered as the drainage end in the hori direction.
      CALL HDIST (UB,XT,IEND,ICV,CHIN,DXSQ,AAH,MHE,W,XET,IPOR,
     *  HF,MYE,POR)
516   IF (ISP.EQ.1) GO TO 510
      WRITE (IOUTP,941) FSI,SPECS(LIFT),SPECU(LIFT),IEND
      WRITE (IOUTP,960) TL(LIFT),LIFT,FS,FSI
      WRITE (IOUTP,902)
C
C Compute Immediate settlements, SETI, if B.NE.1 compute
C pore pressures UAVED from UB, if IRP=0 or from UB+UC,
C if IRP.NE.0, write information on tape 1.
C
510   IF (B.NE.1.) GO TO 402
      DO 403 I=1,IEND
403   SETI(I)=0.
      GO TO 405
402   CALL SETL (UB,SETC,IEND,KKK,MYE,1.,FUP,FLO,KIAV)
      AI=1./B
```

```
      CALL SETL (UB,SETT,IEND,KKK,MYE,AI,FUP,FLO,KIAV)
      DO 404 I=1,IEND
 404  SETI(I)=SETT(I)-SETC(I)
 405  II=0
      DO 121 I=1,IEND
      SETC(I)=0.
      SETT(I)=SETI(I)
      UAVE(I)=0.
      UAVED(I)=0.
      UAVEM(I)=0.
      WRITE (1) SETI(I),SETC(I),SETT(I),UAVE(I)
      DO 122 J=1,MYE
      II=II+1
      UD(II)=UB(II)+UC(II)
      UAVED(I)=UAVED(I)+UD(II)*SV(J)
      UM(II)=UB(II)/B+UC(II)
      UAVEM(I)=UAVEM(I)+UM(II)*SV(J)
      UC(II)=UB(II)
 122  UB(II)=UD(II)
 121  CONTINUE
C
C Determine soil parameters in a form suitable for the subroutine
C DISP. Only one OMEGA- and ONE PHI- element for the case of
C constant soil parameters and full saturation.
C
      if (IEND.GT.5) goto 1241
      CALL LAGR (XET,UE,N,1,XT,UAVEM,IEND)
      CALL LAGR (XET,UF,N,1,XT,UAVED,IEND)
      go to 1242
 1241 call LINT (XET,UE,N,N,XT,UAVEM,IEND)
      call LINT (XET,UF,N,N,XT,UAVE,IEND)
 1242 IF (IVAR.NE.0) GO TO 124
      PHI(1)=CV/DYSQ
      OMEGA(1)=0.
      IF (HF.GT.0.) OMEGA(1)=CH/DXSQ
      GOTO  123
 124  KOUNT=1
      CALL COEF (UAVEM,UAVED,OMEGA,PHI,1,1,OMED,PHID,IEND)
      IF (HF.EQ.0.) GO TO 125
      CALL COEF (UE,UF,OMEGA,PHI,1,2,OMED,PHID,N)
 125  KOUNT=0
C
C CONDITIONS IN THE CONSOLIDATION PROCESS.
C
 123  CALL DISP (UB,5,OMEGA,PHI,0.,UAVE,1,MYE,IEND,XT,SV)
C
C
C SECOND OR FOLLOWING LOAD
C ***********************************************************
C
C Read characteristics of next load depending on the value of
C LIFT+1.
C Define the index ISTAB.
C  ISTAB=0 Determine the factor of safety.
C  ISTAB=1 NO stability analysis. ISTAB is set equal to 1 if
C          pore pressures at special points are to be computed
C          ISP=1
C  FSI=secified factor of safety for the LL-th load distribution.
C  SPECS= specified fraction of the consolidation settlement.
C  SPECU-- if an average degree of consol. of 0.95 due to the
```

```
C  lift-th load is obtained at SPECU(LIFT)*IEND points XT without
C  a sufficient factor of safety for the LL-th load the LIFT-th
C  load is taken to be the last load and NL is set NL=LIFT.
C  TMIN  first stability analysis for the LL-th load will be
C  done.
C  for TD.GE.TMIN days after application of the LIFT-th load.
C  XC,YC =coord of the center of the first trial arc.
C  If IAB.NE.0 new pore pressure parameters A and B are input.
C
 128     IF (LL.GT.NL) GOTO 129
         READ (INPUT,*) MINP,NS,IAB
         DO 130 I=1,MINP
 130     READ (INPUT,*) XINP(I),YINP(I)
         IF (IAB.NE.0) READ (INPUT,*) A,B
         ISTAB=ISP
         IF (ISP.EQ.1) GO TO 518
         READ (INPUT,*) FSI,SPECS(LL),SPECU(LL),TMIN,XC,YC,ZZ
         CALL INIT (XINP,YINP,MINP,XC,YC,YY,ZZ,DMIN)
         GO TO 129
 518     TSTEP=TL(LL)-TL(LIFT)
 129     ITB=ITB+1
         IF (ITB.GT.ITBL) GO TO 200
C
C Compute pore pressures at time T(IT). Determine variable soil
C parameters. Compute consol. settlements. Perform stability
C analysis.
C
         TD=TB(ITB)
         IT=IT+1
         IF (ISP.EQ.0) GOTO 131
         IF (LL.GT.NL) GO TO 131
         IF (TSTEP.LT.TD) TD=TSTEP
 131     T(IT)=TL(LIFT)+TD
         CALL DISP (UB,2,OMEGA,PHI,TD,UAVE,LIFT,MYE,IEND,XT,SV)
C
C Vector UB contains the pore pressures at time T(IT). Vector UVAE
C contains the average pore poressures as computed from UB.
C Vector UA contains the dissipated pore pressures up to time T(IT).
C
         IF (IVAR.EQ.0) GO TO 232
         if (IEND.GT.5) go to 2321
         CALL LAGR (XET,UF,N,1,XT,UAVE,IEND)
         go to 2322
 2321    call LINT (XET,UF,N,N,XT,UAVE,IEND)
 2322    CALL COEF (UAVEM,UAVE,OMEGA,PHI,3,1,OMED,PHID,IEND)
         CALL COEF (UE,UF,OMEGA,PHI,3,2,OMED,PHID,N)
         CALL DISP (UB,3,OMED,PHID,TD,UAVE,LIFT,MYE,IEND,XT,SV)
 232     IF (LL.GT.NL) GO TO 133
         IF (ISTAB.EQ.1) GOTO 133
         IF (TD.LT.TMIN) GO TO 133
         DO 72 J=1,ISUM
         UA(J)=UM(J)-UB(J)
 72      CONTINUE
         CALL GAIN (UA,R,SU,MYE,MXT,MXE,MX,NIM,CO,CP,0)
         CALL STAB (XC,YC,RR,XINP,YINP,MINP,MX,MYE,SU,FS,DMAX,DMIN,YY)
         IF (FS.LT.FSI) GOTO 75
         ISTAB=1
         WRITE (IOUTP,902)
 75      WRITE (IOUTP,942) T(IT),LL,FS,FSI
         WRITE (IOUTP,842) XC,YC,RR
```

```
C
C Compute settlements and average degrees of consolidation.
C Count at how many points XT the degree of consolidation as
C compared to the pore pressures at the time of the last load
C application is greater than 95%.
C
 133    UCHEK=0.
        DO 132 J=1,ISUM
        UA(J)=UD(J)-UB(J)
 132    CONTINUE
        CALL SETL (UA,SETC,IEND,KKK,MYE,1.,FUP,FLO,KIAV)
        DO 134 I=1,IEND
        SETT(I)=SETI(I)+SETC(I)
        IF (UAVE(I).LT.(0.05*UAVED(I))) UCHEK=UCHEK+1.
        UAVE(I)=(UAVED(I)-UAVE(I))/UAVER(I)
        WRITE (1) SETI(I),SETC(I),SETT(I),UAVE(I)
 134    CONTINUE
C
C In the following checks are made for the no. of lift, whether
C the FS is sufficient for the next lift, whether a specified amount
C of settlement at point XT(1) has already occured, whether the
C available construction time TA has been passed, and whether an
C average degree of consol. relative to the pore pressures at the time
C of load application of 95% has been reached at .GE.SPECU(LIFT)*IEND
C points XT
C
        IF (LIFT.EQ.NL) GOTO 129
        IF (ISP.EQ.0) GO TO 135
        IF (TD.EQ.TSTEP) go to 137
        GO TO 129
 135    IF (ISTAB.EQ.0) GO TO 138
        IF (SETC(1).GT.SPECS(LIFT)*SETRC(1)) GO TO 137
 138    IF (T(IT).GT.TA) GO TO 139
        IF (UCHEK.LT.AIEND*SPECU(LIFT)) GO TO 129
        NL=LIFT
        III=UCHEK+0.1
        WRITE (IOUTP,948) III,IEND,TL(LIFT),LIFT
        GO TO 129
C
 139    NL=LIFT
```

This page is left blank intentionally.

```
      WRITE (IOUTP,949) FS,SETC(1),T(IT),TA,LIFT
      GO TO 129
C
 137  LIFT=LL
      LL=LIFT+1
      ITB=1
      TL(LIFT)=T(IT)
      IT=IT+1
      T(IT)=TL(LIFT)
      WRITE (IOUTP,900)
      WRITE (IOUTP,939) LIFT,TL(LIFT)
      WRITE (IOUTP,916) A,B
      WRITE (IOUTP,930) QLOAD,CLOAD,YWM,TQPHI,MINP
      DO 140 I=1,MINP
 140  WRITE (IOUTP,931) XINP(I),YINP(I)
      WRITE (IOUTP,902)
C
C compute pore pressures due to new load. Compute imm. settlements,
C SETI,if B.NE.1. Note that the consol. settlements, SETC and the
C ave. degree of consol are the same as computed at time
C T(IT-1)=TL(LIFT).
C
C Note pore pressures due to the load addition are neglected in
C the computation of imm. settlements. Since zero swelling is
C assumed, negative pore pressures after load application are
C set equal to zero. Thismeans that negative pore pressures due
C to load removal are considered only in a magnitude equal to
C the not dissipated pore pressures jjust before load removal.
C
      IF (IDEN(LIFT).EQ.0) GO TO 76
      DO 77 I=1,ISUM
      UA(I)=UU(I)
 77   CONTINUE
      GO TO 78
 76   CALL PORE (XINP,YINP,MINP,NS,XT,IEND,YE,MYE,UA,A,B)
 78   IF (ISP.EQ.1) GO TO 511
      WRITE (IOUTP,941) FSI,SPECS(LIFT),SPECU(LIFT),IEND
      WRITE (IOUTP,960) TL(LIFT),LIFT,FS,FSI
      WRITE (IOUTP,902)
511         IF ((1.-B).LT.0.00001) goto 143
      CALL SETL (UA,SETRI,IEND,KKK,MYE,1.,FUP,FLO,KIAV)
      AI=1./B
      CALL SETL (UA,SETT,IEND,KKK,MYE,AI,FUP,FLO,KIAV)
      do 141 I=1,IEND
      SETRI(I)=SETT(I)-SETRI(I)
      IF (SETRI(I).GT.SETI(I)) SETI(I)=SETRI(I)
      SETT(I)=SETI(I)+SETC(I)
 141  CONTINUE
C
 143  II=0
      DO 144 I=1,IEND
      WRITE (1) SETI(I),SETC(I),SETT(I),UAVE(I)
      UAVE(I)=0.
      UAVED(I)=0.
      UAVEM(I)=0.
      DO 144 J=1,MYE
      II=II+1
      UT=UB(II)+UA(II)-UC(II)
      IF (UT.LT.0.) UT=0.
      UAVE(I)=UAVE(I)+UT*SV(J)
```

```
      UB(II)=UT-UB(II)
      UC(II)=UA(II)
      UD(II)=UD(II)+UB(II)
      UAVED(I)=UAVED(I)+UD(II)*SV(J)
      UM(II)=UD(II)+(1./B-1.)*UA(II)
      UAVEM(I)=UAVEM(I)+UM(II)*SV(J)
144   CONTINUE
      LLL=LIFT-1
      CALL DISP (UB,3,OMEGA,PHI,TD,UAVE,LLL,MYE,IEND,XT,SV)
      IF (IVAR.EQ.0) GO TO 244
      if (IEND.GT.5) goto 1444
      CALL LAGR (XET,UF,N,1,XT,UAVE,IEND)
      CALL LAGR (XET,UE,N,1,XT,UAVEM,IEND)
      goto 1445
1444  call LINT (XET,UF,N,N,XT,UAVE,IEND)
      call LINT (XET,UE,N,N,XT,UAVEM,IEND)
1445  CALL COEF (UAVEM,UAVE,OMEGA,PHI,1,1,OMED,PHID,IEND)
      CALL COEF (UE,UF,OMEGA,PHI,1,2,OMED,PHID,N)
244   CALL DISP (UB,1,OMEGA,PHI,0.,UAVE,LIFT,MYE,IEND,XT,SV)
      GO TO 128


200   rewind 1
      write(IOUTP,5013)
5013  format ('Reached end of file')
      REWIND 2

OUTPUT OF RESULTS
*********************************************************

Write title for output of results of the consol. process.

      WRITE (IOUTP,901)
      WRITE (IOUTP,950)
      IF (ISP.EQ.1) GO TO 217
      DO 218 I=1,JND
      K=JSP(I)
218   XRP(I)=W*XE(K)


Determine indices MXS(I),I=1,NIM and matrix RSP which is a sub
matrix of matrix R. Matrix RSP is needed when interpolation between
points XT is done to get the information required at points XRP/W.

      IRE=0
      IRS=0
      K=1
      MMM=MXE(1)
      MT=MXT(1)
      DO 210 JJ=1,NIM
210   MXS(JJ)=0

      JJ=1
      DO 211 I=1,MX
      IF (JSP(K).EQ.I) GO TO 214
      GO TO 215
214   DO 212 J=1,MT
      IRS=IRS+1
      IRE=IRE+1
212   RSP(IRS)=R(IRE)
```

```
C
      MXS(JJ)=MXS(JJ)+1
      IF (K.EQ.JND) GOTO 213
      K=K+1
 215  IF (MMM.NE.I) GO TO 211
      JJ=JJ+1
      MT=MXT(JJ)
      MMM=MMM+MXE(JJ)
 211  CONTINUE
C
C
C CASE THAT ISP=1
C
 217  JND=IEND
      DO 219 I=1,JND
 219  XRP(I)=W*XT(I)
C
 213  WRITE (IOUTP,951) (XRP(I),I=1,JND)
      WRITE (IOUTP,900)
      DO 250 I=1,JND
 250  XRP(I)=XRP(I)/W
C
C
      MMM=2
      IF (B.NE.1.) MMM=4
      MT=MMM*JND
C
C Read UAVE,SETC and SETT, given at points XT from TAPE 1. if
C ISP=1, this is the information to be output. IF ISP=0,
C perform interpolation using matrix RSP. Outpiy the
C information and store it on TAPE 2 for later plots for times
C T(J), J=1,IT. Use UA and UB for temporary storage.
C
      DO 220 J=1,IT
      II=1
      DO 221 I=1,IEND
      READ (1) AI,UA(II+1),AA,UA(II)
       IF ((1.-B).LT.0.00001) GOTO 224
      UA(II+2)=AI
      UA(II+3)=AA
 224  II=II+MMM
 221  CONTINUE
      IF (ISP.EQ.1) GO TO 225
C
C Interpolation for points XRP(I)/W by means of matrix multi-
C plication. Information for points XT is in UA. Interpolation
C for points XRP(I)/W is stored in UB
C
      IUBE=0
      IUND=0
      IRND=0
      DO 216 JJ=1,NIM
      IUBS=IUBE+1
      IUBE=IUBE+MMM*MXT(JJ)
      IF (MXS(JJ).EQ.0) GO TO 216
      IUST=IUND+1
      IUND=IUND+MMM*MXS(JJ)
      IRST=IRND+1
      IRND=IRND+MXT(JJ)*MXS(JJ)
      CALL MPRD (UA,RSP,UB,MMM,MXT(JJ),MXS(JJ),IUBS,IRST,IUST)
```

```
216    CONTINUE
       GO TO 226

 DEFINE UB FOR CASE OF ISP=1

225    DO 222 I=1,MT
222    UB(I)=UA(I)

226    IF (J.EQ.1) GO TO 227
       IF (T(J).NE.T(J-1)) GO TO 228
227    WRITE (IOUTP,952) T(J)
228    WRITE (IOUTP,953) T(J)

       DO 223 K=1,MMM
       WRITE (IOUTP,951) (UB(I),I=K,MT,MMM)
223    CONTINUE

       WRITE (2) (UB(I),I=1,MT)

220    CONTINUE


       REWIND 1
       REWIND 2


 PLOTTING ROUTINE
 *******************************************************


       KEND=T(IT)/7.+1.001
       IF (LND.GT.KEND) LND=KEND

 Compute the reference settlement for points XRP from total
 settlements SETRT at points XT.

       IF(ISP.EQ.0) GO TO 297
       DO 298 I=1,IEND
298    SETR(I)=SETRT(I)
       GO TO 299

297    IUBE=0
       IUND=0
       IRND=0
       DO 406 I=1,NIM
       IUBS=IUBE+1
       IUBE=IUBE+MXT(I)
       IF (MXS(I).EQ.0) GO TO 406
       IUST=IUND+1
       IUND=IUND+MXS(I)
       IRST=IRND+1
       IRND=IRND+MXT(I)*MXS(I)
       CALL MPRD (SETRT,RSP,SETR,1,MXT(I),MXS(I),IUBS,IRST,IUST)
406    CONTINUE

299    DO 300 J=1,JND
       JS=(J-1)*MMM+1

 WRITE TITLE FOR J-TH PLOT
```

```
      X=XRP(J)*W
      WRITE (IOUTP,901)
      WRITE (IOUTP,954) X,SETR(J),SYMB(1),SYMB(2)
      IF (MMM.EQ.4) WRITE (IOUTP,955) SYMB(3),SYMB(4)
      WRITE (IOUTP,900)
C
      REWIND 2
      READ (2) (UB(I),I=1,MT)
C
C GENERATE FIRST LIN TO BE PRINTED
C
      LOUT=T(1)/7.+0.1
      JT=2
      K=T(2)/7.+0.1
      DO 301 I=1,76
 301  ROW(I)=STAR
      DO 302 I=6,71,5
 302  ROW(I)=GRID
C
      JJ=JS
      II=50.*UB(JJ)+1.5
      ROW(II)=SYMB(1)
C
      DO 303 I=2,MMM
      JJ=JJ+1
      II=50.*UB(JJ)/SETR(J)+1.5
 303  ROW(II)=SYMB(I)
C
C Write first line and clear ROW(I) afterwards.
C
      WRITE (IOUTP,957)
      WRITE(IOUTP,956) LOUT,(ROW(I),I=1,76)
      DO 304 I=2,75
 304  ROW(I)=BLANK
      ROW(1)=STAR
      ROW(76)=STAR
      MK=MMM
C
C Determine the following to be printed.
C
      DO 306 L=2,LND
      LOUT=LOUT+1
      IF(K.EQ.LOUT) GO TO 305
      WRITE (IOUTP,956) LOUT,(ROW(I),I=1,76)
      GO TO 306
 305  JT=JT+1
      IF (JT.GT.IT) JT=1
      K=T(JT)/7.+0.1
C
C Read data from TAPE and determine symbols to be printed
C
 309  READ (2) (UB(I),I=1,MT)
      JJ=JS
      IKK=MK-MMM+1
      II=50.*UB(JJ)+1.5
      ROW(II)=SYMB(1)
      KK(IKK)=II
C
      DO 307 I=2,MMM
      JJ=JJ+1
```

```
      IKK=IKK+1
      II=50.*UB(JJ)/SETR(J)+1.5
      ROW(II)=SYMB(I)
      KK(IKK)=II
307   CONTINUE

      IF (K.NE.LOUT) GO TO 310
      JT=JT+1
      K=T(JT)/7.+0.1
      MK=MK+MMM
      GO TO 309

 Print the L-th line and BLANK out the second through 75-th
 element.
310   WRITE (IOUTP,956) LOUT,(ROW(I),I=1,76)
      DO 308 I=1,MK
      II=KK(I)
308   ROW(II)=BLANK
      ROW(1)=STAR
      ROW(76)=STAR
      MK=MMM
306   CONTINUE

 Generate and print last line
      DO 311 I=1,76
311   ROW(I)=STAR
      DO 312 I=6,76,5
312   ROW(I)=GRID
      LOUT=LOUT+1
      WRITE (IOUTP,956) LOUT,(ROW(I),I=1,76)
300   CONTINUE

       IF (NL.NE.NLS) GOTO 10000
      GO TO 100


 FORMAT STATEMENTS
 ******************************************

:91   FORMAT (15I4)
:92   FORMAT (8F8.3)
:93   FORMAT (4E10.5)
:94   FORMAT (7A1)

?00   FORMAT (//////)
?01   FORMAT (1H1)
?02   FORMAT (//)
?03   FORMAT (1H ,25x,'*************************************',/
   1            1H ,25x,'*                                   *',/
   2            1H ,25x,'*      CONSOLIDATION PROBLEM        *',/
   3            1H ,25x,'*                                  *',/
   4            1H ,25x,'*     STEP LOADING & SURCHARGE      *',/
   5            1H ,25x,'*************************************')
?04   FORMAT (1H ,10X,'THE PORE WATER PRESSURES ARE COMPUTED AT')
?05   FORMAT (1H ,10X,'  YE/H   ',5f10.3)
?06   FORMAT (1H ,10X,'  XT/W   ',5f10.3)
?07   FORMAT (1HO,10X,'THE PORE PRESSURES ARE INTERPOLATED AT')
?08   FORMAT (1H ,10X,'  XE/W=   ',5f10.3)
?09   FORMAT (1H ,10X,'ASSUMING COLLOCATION POLYNOMIALS OF DEGREE  ')
?10   FORMAT (1H ,10x,I1,' BETWEEN THE LIMITS  ',f8.3,' AND ',f8.3)
```

```
 911     FORMAT (1HO,10x,'HORIZONTAL PORE PRESSURES ARE COMPUTED AT')
 912     FORMAT (1H ,10x,'  X=   ',5f10.3)
 913     FORMAT (1HO,10X,'THE SUBSOIL IS DESCRIBED BY THE FOLLOWING'/
     1   11x,'parameters which are given for the upper layer'/
     2            1H ,10X,'IN CASE OF STRATIFICATION'//)
C
C
 914     FORMAT (1H ,10x,'TOTAL THICKNESS  ','H=',f8.3,'  FEET  '/
     1            1H ,10x,'reference for X-COORD W = ',f8.3,' FEET')
 915     FORMAT (1HO,10X,'LAYER INTERFACE IS ',f8.3,' FT BELOW SURFACE',/,
     2            1H ,10x,'LOWER/UPPER PERMEABILITY, RK= ',f8.3,/,
     3            1H ,10x,'LOWER/UPPER COEF.OF.CONSOLIDATION,RC= ',f8.3/
     4            1H ,10x,'LOWER/UPPER INITIAL VOID RATIO, REO= ',f8.3)
 815     FORMAT (1H ,10x,'LOWER/UPPER COEF.OF.COMPRESS, RAV= ',f8.3)
 715     FORMAT (1H ,10x,'LOWER/UPPER COMPRESSION INDEX,RCC= ',f8.3/
     1       1H ,10x,'LOWER/UPPER RECOMPRESSION INDEX RROCL = ',f8.3)
 916     FORMAT (1H ,10X,'SKEMPTON PORE PRESSURE COEFFICIENTS ARE',/
     1            1H ,10X,' A= ',F5.2,' AND B= ',F5.2,//)
 917     FORMAT (1H ,10X,'DEGREE OF SATURATION IS S= ',F5.3,/
     1   1H ,10X,'HENRY-S CONSTANT OF GAS SOLUBILITY HC = ',F7.3,/
     2            1H ,10x,'INITL PORE GAS PRESSURE IS PU= ',E12.4,' PSF')
 918     FORMAT (1H ,10X,'INITIAL VOID RATIO = ' ,F6.3)
 818     FORMAT (1H ,10X,'INITIAL COEFF. OF COMPRESSIBILITY IS AVO= ',/
     1       1H ,10x,E12.4,' FT*FT /LB.')
 919     FORMAT (1H ,10X,'THE COMPRESSION INDEX IS =  ',E12.4,/
     1            1H ,10X,'RECOMPRESSION INDEX/CC   ROC= ',F8.3)
 819     FORMAT (1H ,10X,'INITIAL EFFECTIVE P AND PRECOMPRESSION',/
     1            1H ,10X,'STRESSES PC AS USED IN THE COMPUTATIONS',/
     2            1H ,10X,'Y IN FT',5X,'P IN PSF',4X,'PC IN PSF')
 719     FORMAT (1H ,10X,F9.3,2F13.2)
 619     FORMAT (1HO,10X,'NOTE -P(1) AND PC(1) MAY HAVE BEEN CHANGED',/
     1            1H ,10X,'as compared to input values to avoid over flow')
 920     FORMAT (1H ,10X,'THE INITIAL PERMEABILITIES ARE IN',/
     1            1H ,10x,'VERTICAL DIRn. KVO=  ',E12.4,'  FT/DAY',/
     2            1H ,10x, 'HORIZONTAL DIRN KHO= ',E12.4,' FT/DAY')
 820     FORMAT (1H ,10X,'THE FOLLOWING COEFF. OF CONSOLIDATION',/
     1            1H , 10X,'ARE IN PUT AT SPECIFIED EFFECTIVE STRESSES',/
     2            1HO,3x,'EFF-STRESS(PSF)',2x,'V-COEF(FT*FT/DAY)',
     3            2x,'EFF-STRES(PSF)',2x,'H-COEF(FT*FT/DAY)')
 720      FORMAT (1H ,7x,f10.2,7x,E12.4,7x,f10.2,7x,E12.4)
 921     FORMAT (1H ,10X,'THE SLOPES OF THE E Vs LOG(K)-CURVES ARE',/
     1            1H ,10x,'IN VERTICAL DIRN, SKV=  ',F8.3,/
     2            1H ,10x,'IN HORI. DIRN, SKH=   ',F8.3)
 922     FORMAT (1HO,10X,'THE DRAINAGE CONDITIONS ARE')
 926     FORMAT (1H ,10X,'IMPEDED DRAINAGE AT THE BOTTOM WITH',/
     1            1H ,10X,'VERT. PERM/VERT. IMPEDED PERM RKV=  ',F5.2,/
     2            1H ,10X,'THICKNESS OF IMPEDED LAYER, HI=  ',F8.3,'FT')
 927     FORMAT (1H ,10X,'FREE DRAINAGE AT THE BOTTOM')
 928     FORMAT (1H ,10X,'NO DRAINAGE AT THE BOTTOM')
 930     FORMAT (1H ,10X,'THE LOAD CHARACTERISTICS ARE GIVEN BY',/
     1            1H ,10X,'THE UNIT WEIGHT GLOAD=  ',F7.2,'  PCF',/
     2            1H ,10X,'THE COHESION , CLOAD=  ',F8.2,' PSF',/
     3       1H ,10x,'THICKNESS OF THE DRAINAGE BLANKET YWM=',f6.2,'FT',/
     4         1H ,10x,'THE TANGENT OF THE ANGLE ',/
     5            1H ,10X,'OF INTERNAL FRICTION TGPHI=  ',F7.4,/
     6            1H ,10X,'MINP=  ',I3,' COOR POINTS XINP/YINP')
 931     FORMAT (1H ,20X,F10.2,' FEET ',F10.2,' FEET')
 932     format (1H ,10X,'THE AVERAGE PORE PRESSURES, UAVER(I)',/
     1            1H ,10X,'THE CONSOLIDATION SETTLEMENTS, SETRC(I) AND THE',
     2            1H ,10X,'TOTAL SETTLEMENTS,SETRT(I),AT XT(I) ARE',/
```

```
   3           1H ,10X,'XT FEET',4X,'UAVER (PSF)',3X,'SETRC',/
   4            ' FEET',3X,'SETRT FEET')
933     FORMAT (1H ,10x,f7.2,4x,f12.2,4x,f9.3,3x,f9.3)
934     FORMAT (1H ,10X,'COEFF OF CONSOL. VERT FLOW IS CV= ',/
   1           1H ,10X,E12.4,' FEET**2/DAY',/
   2           1H ,10X,'COEF. OF CONSOL. HORI. FLOW IS CH= ',/
   3    1H ,10x,E12.4,' FT**2/DAY')
935     FORMAT (1H0,10X,'REFERENCE LOAD',/
   1           1H ,10X,'**************')
936     FORMAT (1H ,10X,'THE NUMBER OF LIFTS IS NL= ',I3)
937     FORMAT (1H ,10X,'SINCE ISP=1 TIMES OF LOAD APPLICATION',/
   1           1H ,10X,'ARE INPUT TO BE',///)
938     FORMAT (1H ,10X,'TL(',I2,')= ',F6.0,' DAYS')
939     FORMAT (1H0,10X,'LOAD NO ',I3,' APPLIED AT TL= ',F6.0,'DAYS',/
   1           1H ,10X,'*******************')
940     FORMAT (1H0,10X,'THE AVAILABLE CONSTRUCTION TIME IS TA= ',/
   1           1H ,10X,F6.0,' DAYS. TA IS NOT NEEDED IF NL=1')
840     FORMAT (1H ,10X,'PARAMETERS USED IN THE STABILITY ANALYSIS',/
   1           1H0,10X,'DMAX= ',F8.3,5X,'DMIN= ',F8.3,/
   2           1H ,10X,'NARC= ',I4,'NRAD= ',I4,/
   3           1H ,10X,'DMAX, DMIN ARE THE MAX AND MIN STEP SIZES',/
   4           1H ,10X,'USED IN THE SEARCH PROCEDURE',/
   5           1H ,10X,'NARC=ONE- HALF THE NUMBER OF SUB ARCS',/,
   6           1H ,10X,'NRAD=NUMBER','OF RADII USED FOR EACH TRIAL CENTER',/
   7           1H ,10X,'OF ARCS')
941     FORMAT (1H ,10X,'THE REQUIRED SAFETY FACTOR IS FSI= ',F6.3,/
   1           1H ,10X,'THE SPECIFIED PORTION OF SETLEMENT IS',/
[illegible]
   3           1H ,10X,' IF 95% OF THE AVE PORE PRESSURE',/
   4           1H ,10X,'AT THE TIME OF APPLICATION OF THIS LOAD',/
   5           1H ,10X,'HAVE DISSIPATED AT ',F6.4,'*',I2,'POINTS XT',/
   6           1H ,10X,'THIS LIFT IS ASSUMED TO BE THE LAST ONE',/)
942     FORMAT (1H0,10X,'THE FACTOR OF SAFETY AT TIME T= ',F6.0,/
   1           1H ,10X,'DAYS FOR LIFT ',I3,' IS FS= ',F6.3,/
   2           1H ,10X,'AS COMPARED TO THE REQU. FSI= ',F6.3)
842     FORMAT (1H ,10X,'FS HAS BEEN OBTAINED FOR THE ARC WITH',/
   1           1H ,10X,'X=',F8.2,' Y= ',F8.2,' RADIUS= ',F8.2,' IN FT')
943     FORMAT (1H ,10X,'SINCE FS.LT.FSI, TERMINATE THE PROGRAM')
944     FORMAT (1H ,10X,'RESIDUAL PORE PRESSURES AS INPUT IN PSF',/
   1           1H ,10X,'YE(I)/H=',12X,11F9.3)
945     FORMAT (1H ,'X(',I2,')/W= ',F8.3,4X,11F9.3)
946     FORMAT (1H0,10X,'RESIDUAL PORE PRESSURES ARE IN PUT AS',/
   1           1H ,10X,3X,'X (FEET)',3X,'Y (FEET)',3X,'UC (PSF)')
947     FORMAT (1H ,10X,3F12.3)
948     FORMAT (///,1H ,10X,'AT ',I3,' OUT OF ',I3,' POINTS XT',/
   1           1H ,10X,'AN AVE DEGREE OF CONSOL. OF 95%',/
   2           1H ,10X,'HAS COMPARED TO PORE PRESSURES AT THE TIME T= ',/
   3           1H ,10X,F6.0,' DAYS OF LAST LOAD APPLICATION',/
   4           1H0,10X,'*** THIS LIFT NO. ',I3,/
   5           1H ,10X,'IS THEREFORE CONSIDERED TO BE THE LAST ONE***',///)
949     FORMAT (///,1H ,10X,'EITHER THE FACTOR OF SAFETY, FS= ',F6.3,/
   1           1H ,10X,'AND/OR THE SETTLEMENT, SETC(1)= ',F6.3,'FEET',/
   2           1H ,10X,'ARE LESS THAN SPECIFIED AT TIME T= ',F6.0,'DAYS',/
   3           1H ,10X,'WHICH IS GREATER THAN TA= ',F6.0,'DAYS',/
   4           1H0,10X,'*** THIS LIFT NO ',I3,' IS, THEREFORE',/
   5           1H ,10X,'CONSIDERED TO BE THE LAST ONE***',///)
950     FORMAT (1H0,10x,'THE CONSOL. PROCESS',/
   1           1H ,10x,'*********************',//////,
   2           1H ,10X,'THE FOLLOWING INFORMATION IS OUT PUT',/
   3           1H0,10X,'UAVE(X(1)),UAVE(X(2)),........,',/
```

```
    4           1H ,10X,'= AVER DEGREES OF CONSOL. WITH RESPECT TP REF. LC
    5           1H ,10X,'SETC(X(1)),SETC(X(2)),.......,'/
    6           1H ,10X,'= CONSOL. SETTLEMENTS',/
    7           1H ,10X,'SETI(X(1)),SETI(X(2)),.......,'/
    8           1H ,10X,'= IMMMEDIATE SETTLEMENTS',/
    9           1H ,10X,'SETT(X(1)),SETT(X(2)),.......,'/
    *           1H ,10X,'= CONSOLI. + IMMMEDIATE SETTLEMENTS',/
    1           1H0,10X,'LAST TWO LINE ARE ONLY OUT PUT',/
    2           1H ,10X,'IF SOIL IS PARTIALLY SATURATED (S.NE.1.)',/
    3           1H0,10X,'THE POINTS X(I) IN FEET ARE AS FOLLOWS',//)
 951     format (2x,10F8.3)
 952    FORMAT (/,1H ,10X,'T= ',F6.0,/
    1           1H ,10X,'DAYS IS THE TIME OF LOAD APPLICATION',/)
 953    FORMAT (/,1H ,10X,'T= ',F6.0,'DAYS',/)
 954    FORMAT (1H0,10X,'AVE DEGREE OF CONSOL. AND SETTLEMENT',/
    1           1H ,10X,'CURVES FOR POINT X= ',F8.2,'FEET FROM CENTER LINE
    2           1H ,10X,'INTERVAL BETWEEN 2 GRID LINES.EG.10%',/
    3           1H ,10X,'ABSCISSA NUMBERS GIVE THE TIME IN WKS',/
    4           1H ,10X,'THE TOTAL SETTL DUE TO REFERENCE LOAD IS',/
    5           1H ,10X,E10.3,' FEET',/
    6           1H0,10X,A1,' -CUREV= AVE. DEGREE OF CONSOL.',/
    7           1H ,10X,'RELATIVE TO THE PORE PRESS DUE TO REF LOAD',/
    8           1H0,10X,A1,' -CURVE=CONSOL. SETTL. IN % OF',/
    9           1H ,10X,'REF. SETTLEMENT')
 955    FORMAT (1H ,10X,A1,' -CURVE=IMMEDIATE SETTLEMENTS IN % OF',/
    1           1H ,10X,'THE REFERENCE SETTLEMENTS',/,
    2           1H ,10X,A1,' -CURVE=TOTAL SETTLEMENTS IN % OF',/,
    3           1H ,10X,'THE REFERENCE EHSETTLEMENT',/)
956     format (1H ,i3,76A1)
 957    FORMAT (1H#,2X,'0.0  0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8 ',
    1           '0.9  1.0  1.1  1.2  1.3  1.4  1.5',//)
 960    FORMAT (1H0,10X,'THE FACTOR OF SAFETY AT TIME T= ',F6.0,/,
    1           1H ,10X,'DAYS FOR LIFT',I3,'WAS .GE.FS= ',F6.3,/,
    2           1H ,10X,'AS COMPARED TO THE REGU. FSI= ',F6.3)
 962    format (1H ,20x,f8.3,12x,f8.3,12x,f8.3)
 194     format (7A1)
 961    format (1H ,10x,'THE SHEAR STRENGTH CHARACTERISTICS OF',/,
    1           1H ,10X,'THE SUB SOIL AS USED IN THE STABILITY ANALYSIS AR
    2           1H0,15x,'DEPTH (FT)',5x,'COHESION (PSF)',5x,'P-RATIO')
10000   END
        subroutine LINT (X,Y,N1,M,XX,YY,N)
        dimension X(1),Y(1),XX(1),YY(1)
C This subroutine interpolates the values of function Y(X)
C from the known YY(XX) by use of the linear interpolation.
C or extrapolation.
C
            II=0
        JJ=0
        NN=M-N1+1
        do 20 I=NN,M
           II=II+1
        J=1
C Extrapolation is used if X(II).GT.XX(N)
        if (X(II).LT.XX(N)) go to 31
        Y(I)=YY(N)+(YY(N)-YY(N-1))*(X(II)-X(N))/(XX(N)-XX(N-1))
        go to 20
 31     if (X(II).GT.XX(1)) go to 32
C Extrapolation is used if X(II).LT.XX(1)
        iiii=2
        Y(I)=YY(1)-(YY(iiii)-YY(1))*(XX(1)-X(II))/(XX(iiii)-XX(1))
```

```
      goto 20
25    J=J+1
 32   if (X(II).GT.XX(J)) go to 25
C Interpolation is used if XX(1).LT.X(II).LT.XX(N)
C If X(II) is very close to XX(J) then Y(I)=YY(J)
      if (ABS(X(II)-XX(J)).GT.0.00000001) go to 28
      Y(I)=YY(J)
      go to 20
28    XY1=XX(J-1)
      YY1=YY(J-1)
      Y(I)=YY1+(X(II)-XY1)*(YY(J)-YY1)/(XX(J)-XY1)
 20   continue
      return
      end
C BEGIN SUBROUTINE INTEG
C
      SUBROUTINE INTEG (ETA,XI,B,AR)
C
C This subroutine computes the values of the stress integrals if
C the integration variable becomes larger than 12.
C
            DIMENSION AR(7)
C
      COMMON/ POAPI/ ALPHA(30),L
C
      PI=3.14159265358979
      ETAP=1.+ETA
      ETAM=1.-ETA
C
      DO 1 I=1,7
 1    AR(I)=0.
C
      DO 2 I=1,L
      pq=1./1000000000000000.
      AMX=ALPHA(I)-XI
      IF (ABS(AMX).LT.pq) GO TO 3
      AR(1)=AR(1)+PI-ATAN(ETAM/AMX)-ATAN(ETAP/AMX)
      IF (AMX.LT.0.) AR(1)=AR(1)-2.*PI
 3    APX=ALPHA(I)+XI
      IF (ABS(APX).LT.pq) GO TO 4
      AR(1)=AR(1)+PI-ATAN(ETAM/APX)-ATAN(ETAP/APX)
      IF (APX.LT.0.) AR(1)=AR(1)-2.*PI
 4    SIAMX=SIN(AMX*B)
C
      COAMX=COS(AMX*B)
      SIAPX=SIN(APX*B)
      COAPX=COS(APX*B)
C
      DPM=1./(ETAP*ETAP+AMX*AMX)
      DPP=1./(ETAP*ETAP+APX*APX)
      DMM=1./(ETAM*ETAM+AMX*AMX)
      DMP=1./(ETAM*ETAM+APX*APX)
C
      SM1=DPM*(ETAP*SIAMX+AMX*COAMX)
      CM1=DPM*(ETAP*COAMX-AMX*SIAMX)
      SP1=DPP*(ETAP*SIAPX+APX*COAPX)
      CP1=DPP*(ETAP*COAPX-APX*SIAPX)
C
      SM2=DMM*(ETAM*SIAMX+AMX*COAMX)
      CM2=DMM*(ETAM*COAMX-AMX*SIAMX)
```

```
      SP2=DMP*(ETAM*SIAPX+APX*COAPX)
      CP2=DMP*(ETAM*COAPX-APX*SIAPX)
C
      AR(2)=AR(2)+SM2+SP2
      AR(3)=AR(3)+SM1+SP1
      AR(4)=AR(4)+DPM*(ETAP*SM1+AMX*CM1)+DPP*(ETAP*SP1+APX*CP1)
      AR(5)=AR(5)+CM2-CP2
      AR(6)=AR(6)+CM1-CP1
      AR(7)=AR(7)+DPM*(ETAP*CM1-AMX*SM1)+DPP*(APX*SP1-ETAP*CP1)
 2    CONTINUE
      EXAP=EXP(-ETAP*B)/2.
      EXAM=EXP(-ETAM*B)/2.
C
      AR(1)=AR(1)/2.
      AR(2)=EXAM*AR(2)*ETAM
      AR(3)=EXAP*AR(3)
      AR(4)=(EXAP*AR(4)+B*AR(3))*2.*ETA
      AR(5)=EXAM*AR(5)*ETAM
      AR(6)=EXAP*AR(6)
      AR(7)=(EXAP*AR(7)+B*AR(6))*2.*ETA
      AR(6)=AR(6)*ETAM
C
      RETURN
      END
C
C END OF SUBROUTINE INTEG
      SUBROUTINE COEF (UAVD,UAVE,OMEGA,PHI,LI,IL,OMED,PHID,NN)
C
C This subroutine determines the soil parameters for the case that
C they are variable.
C If LI=3, the difference between the old and the new parameters
C PHI and OMEGA are also computed and stored in PHID and OMED, resp.
C
      DIMENSION UAVD(1),UAVE(1),OMEGA(1),PHI(1),OMED(1),PHID(1)
      DIMENSION SVM(12),P(11),PC(11),PLOG(11),AA(1),BB(1)
C
      COMMON/ SACSE/ ROC,ROCL,SVM,P,PC,PLOG,PO,PCO,IAV,IK,ISAT,AAV,AAH
      COMMON/ SACO1/ AVO,KVO,KHO,EOPUS,PU,SKHM,SKVM,CCC,NNN,ICOEF
      COMMON/ SACO2/ PCV(10),CVIN(10),PCR(10),CHIN(10),ICV,KOUNT,HF
C
      REAL K,KO,KV,KH,KVO,KHO
C
C Statement functions for the computation of the coeff. of
C permeability. CONK is used, when K is variable and AV is const.
C VARK is used, when K and AV are variable. PSI computes the
C parameters to be returned to the calling program.
C
      CONK(KO,SKM)=KO*EXP(-SKM*DISU)
      VARK(KO,SKM)=KO*(PP/PQ)**(-1.*SKM)
      PSI(AAA,K)=ALPHG*K*AAA/AV
C
C The following parameters have been defined in program SAND and
C are repeated here.
C AAV=(1.+EO)/(GAMMAWATER*(DELTA Y)**2)
C AAH=(1.+EO)/(GAMMAWATER*(DELTA H)**2)
C SKVM=CC/SKV if IAV=1, SKVM=2.3026*AVO/SKV if IAV=0
C SKHM=CC/SKH if IAV=1, SKHM=2.3026*AVO/SKH if IAV=0
C AVO= initial coeff. of compressibility
C KVO,KHO= initial coeff. in vert. and hori. dirns.
C ALPHG =gas factor.
```

```
C IAV=0, constant AV=AVO. IAV=1, variable AV
C IK=0, const. K-s. IK=1, variable K-s.
C NNN=no. of points with vert. and hori. flow.
C KOUNT=0 if the subroutine is called the second or following time
C KOUNT=1 if the subroutine is used for the first time
C ICOEF=1 if IK=0 and IAV=0 or IAV=1
C ICOEF=2 if IK=1 and IAV=0
C ICOEF=3 if IK=1 and IAV=1
C ICOEF=4 if K*(1.+EO)/(GAMMAWATER*AV*DELTA Y**2)=CVIN and
C         K*(1.+EO)/(GAMMAWATER *AV*DELTA H**2)=CHIN are
C         specified at ICV effective stresses PCV and PCH resp.
C ISAT=0 full saturation, ISAT=1 partial saturation
C PO= ave present overburden pressure
C PCO= ave preconsol. pressure
C DISU= UAVD-UAVE= ave dissipated pore pressure
C CCC= 0.4343*compression index
C EOPUS= EO*PU*(1.-S*(1.-HC)), where PU=initial pore gas pressure,
C        S=initial degree of saturation, HC=Henry's const.
C OMEGA(I)= (gas factor*coeff. of consol)/delta H**2
C PHI(I)=(gas factor*coeff. of consol.)/delta Y**2
C OMED(I)=difference between old and new omega(I)
C PHID(I)=difference between old and new PHI(I)

      IF (KOUNT.EQ.0) GO TO 20
      ALPHG=1.
      IF (IAV.EQ.1) PG=CCC/AVO

C Determine OMEGA,PHI, OMED and PHID at NN points

C Determine eff. stresses at the sum of the present overburden
C stress PO and the dissipated pore pressures DISU. Determine
C then the soil parameters as a function of PO+DISU

20    DO 5 I=1,NN
      KK=ICOEF
      DISU=UAVD(I)-UAVE(I)
      PP=PO+DISU
      AV=AVO
      KV=KVO
      KH=KHO
      IF (KK.EQ.4) GOTO 6
      IF (IAV.EQ.0) GO TO 6
      IF (PP.GT.PG) GO TO 31
      KK=1
      GO TO 6
31    AV=CCC/PP
6     IF (ISAT.EQ.0) GO TO 60
      AUX=AV
      IF (PP.LT.PCO) AUX=AUX*ROC
      ALPHG=1./(1.+EOPUS/(AUX*(PU+UAVE(I))**2))
60    IF (IL.EQ.1) GO TO 7
      IF (HF.EQ.0.) RETURN
C
C PARAMETERS FOR HORIZONTAL CASE
C
       if (KK.eq.1) go to 11
       if (KK.eq.2) goto 12
       if (KK.eq.3) goto 13
        go to 14
12    KH=CONK(KHO,SKHM)
```

```
        GO TO 11
 13     KH=VARK(KHO,SKHM)
 11     A=PSI(AAH,KH)
        GO TO 30
C
C INTERPOLATE BETWEEN CHIN(I)
C
 14     BB(1)=ALOG(PP)
        CALL LAGR(BB,AA,1,1,PCH,CHIN,ICV)
        A=ALPHG*AA(1)
 30     IF (LI.EQ.3) OMED(NN+1-I)=OMEGA(NN+1-I)-A
        OMEGA(NN+1-I)=A
        GO TO 5
C
C PARAMETERS FOR VERTICAL CASE
C
7        if (KK.eq.1) goto 1
         if (KK.eq.2) go to 2
         if (KK.eq.3) go to 3
          go to 4
 2      KV=CONK(KVO,SKVM)
        GO TO 1
 3      KV=VARK(KVO,SKVM)
 1      A=PSI(AAV,KV)
        GO TO 40
C
C INTERPOLATE BETWEEN CVIN(I)
C
C
 4      BB(1)=ALOG(PP)
        CALL LAGR (BB,AA,1,1,PCV,CVIN,ICV)
        A=ALPHG*AA(1)
 40     IF (LI.EQ.3) PHID(I)=PHI(I)-A
        PHI(I)=A
 5      CONTINUE
C
        RETURN
        END
C BEGIN SUBROUTINE FUNCT
C
        SUBROUTINE FUNCT (THETA,ETA,K,SIGX,SIGY,TAU)
C
C This subroutine computes the values of the integrands for the
C arguement theta
C
        COMMON/ POFUN/ Q(516),ETHST(516)
C
        TE=ETA*THETA
        ETE=EXP(TE)
        C=(ETHST(K)+1./ETHST(K))/2.
        S=(ETHST(K)-1./ETHST(K))/2.
        CTE=(ETE+1./ETE)/2.
        STE=(ETE-1./ETE)/2.
C
        D=Q(K)/(C*C+THETA*THETA)
        FA=C+THETA*S
        FB=THETA*TE
        FC=THETA*C
        FD=TE*CTE
        FE=TE*STE
```

```
C
C EVALUATE THE INTEGRANDS
C
      SIGX=-D*(FA*(CTE+FE)-FC*(2.*STE+FD))
      SIGY=-D*(FA*(CTE-FE)+FC*FD)
      TAU=+D*(-FA*FD+FC*(CTE+FE))
      IF (ETA.EQ.1.) RETURN
      AUX=2.*Q(K)*CTE/ETHST(K)
      SIGX=SIGX+AUX
      SIGY=SIGY+AUX
      RETURN
      END
C
C END OF SUBROUTINE FUNCT
      SUBROUTINE PORE (XINP,YINP,M,NST,CX,IX,CY,IY,U,ABAR,BBAR)
C
C This subroutine computes the stresses within a compressible
C soil layer by use of elastic theory for plane strain conditions.
C and a symmetric loading. Poissons ratio is 0.5 and the underlying
C stratum is perfectly rough and rigid.
C Pore pressures are computed from a knowledge of the stresses and
C the pore pressure coeff. A and B called herein ABAR and BBAR.
C
      DIMENSION XINP(1),YINP(1),CX(1),CY(1),U(1),SX(220)
      DIMENSION SY(220),TA(220),QX(516),QY(516),QT(516),SI(3)
      DIMENSION SUM(3),R(3),T(3),DIF(3),AR(7),SUMS(3),ABSD(3)
C
      COMMON/ SAPOD/ IOUTP,W,H,GLOAD,CLOAD,NARC,NRAD
      COMMON/ POAPI/ ALPHA(30),L
      COMMON/ POFUN/ QST(516),ETHST(516)
C
C If no load is specified (No. of input points M.LE.1) set pore
C pressures equal to zero and return.
C
      IF (M.GT.1) GO TO 101
      DO 100 I=1,220
100   U(I)=0.
      RETURN
C
C Approximate actual load by NST strips of const. thickness DST.
C
101   CALL APROX (XINP,YINP,M,NST,DST)
      WRITE (IOUTP,94) L
      DO 10 I=1,L
      WRITE (IOUTP,95) I,ALPHA(I)
10    ALPHA(I)=ALPHA(I)/H
C
C Define constants used in the stress computation.
C
      DELTA=0.0001
      DEL=0.001
      DELT=DELTA
      PI=3.14159265358979
      IMAX=512
      AINT=1./512.
      KEND=IMAX+1
      PMAX=NST
      PMAX=ABS(PMAX*PI/2.)
      JEND=12
      FAC=2.*GLOAD*DST/PI
```

```
      ZETA=W/H
      IXIY=IX*IY
      BRAN=2.
C
C Define constant for pore pressure determination.
C
      CONST=0.8660254*(ABAR-1./3.)+1./2.
C
C
C SET STRESSES EQUAL ZERO
C
      DO 21 I=1,IXIY
      SX(I)=0.
      SY(I)=0.
 21   TA(I)=0.
C
      IER=0
C
C Initialize the numerical integration procedure
C Use Simpsons rule if XI.LT.BRAN
C Use Filons formula if XI.GE.BRAN
C Numerical integration is done between 0.0 and REAL(JEND)
C
      DO 5 ISTEP=1,JEND
C
      A=ISTEP-1
      B=ISTEP
      BA=1.
C
      IF (ISTEP.EQ.2) DELT=DEL
C
C Compute factors repeatedly used in suroutine FUNCT
C
      THETA=A-AINT
      DO 2 K=1,KEND
      THETA=THETA+AINT
      ETHST(K)=EXP(THETA)
      QST(K)=0.
C
      DO 2 I=1,L
      QI=ALPHA(I)
      AT=QI*THETA
      ABSAT=ABS(AT)
      IF  (ABSAT.LT.0.001) GO TO 3
      QI=QI*SIN(ABSAT)/AT
 3    IF (AT.LT.0.) QI=-QI
 2    QST(K)=QST(K)+QI
C
C Integrate numerically between the limits A and B and store
C the results in one dimensional arrays SX,SY,TA
C
      DO 5 J=1,IY
      ETO=CY(J)
      ETA=1.-ETO
      DO 51 JQX=1,KEND
 51   QX(JQX)=1.E15
C
C Evaluate the integrand at interval limits A and B
C
      CALL FUNCT (A,ETA,1,QX(1),QY(1),QT(1))
```

```
      CALL FUNCT (B,ETA,KEND,QX(KEND),QY(KEND),QT(KEND))
C
      DO 5 I=1,IX
      LL=(I-1)*IY+J
      XI=CX(I)*ZETA
C
C
C INITIALIZE INTEGRATION
C
      DO 41 K=1,3
41    SI(K)=0.
C
      XIA=XI*A
      XIB=XI*B
      SIXIA=SIN(XIA)
      SIXIB=SIN(XIB)
      COXIA=COS(XIA)
      COXIB=COS(XIB)
      IF (XI.LT.BRAN) GO TO 1
      DIF(1)=QX(KEND)*SIXIB-QX(1)*SIXIA
      DIF(2)=QY(KEND)*SIXIB-QY(1)*SIXIA
      DIF(3)=QT(1)*COXIA-QT(KEND)*COXIB
1     R(1)=QX(1)*COXIA+QX(KEND)*COXIB
      R(2)=QY(1)*COXIA+QY(KEND)*COXIB
      R(3)=QT(1)*SIXIA+QT(KEND)*SIXIB
C
C COMPUTE THE INTEGRAL BY INTERVAL HALVING
C
      NHALF=1
      N=2
6     AN=N
      HH=BA/AN
      XK=A-HH
      XINC=2.*HH
      DO 44 K=1,3
44    T(K)=0.
C
C Compute the values of the integrands if not yet computed and
C store them in QX(K),QY(K),QT(K)
C
      IDEL=IMAX/NHALF
      IT=-IMAX/N+1
      DO 8 K=1,NHALF
      XK=XK+XINC
      IT=IT+IDEL
      pq=1000000000000000.
      IF (QX(IT).EQ.pq) go to 55
      go to 56
55    CALL FUNCT (XK,ETA,IT,QX(IT),QY(IT),QT(IT))
56    XIX=XI*XK

      XIX=XI*XK
      COXIX=COS(XIX)
      T(1)=T(1)+QX(IT)*COXIX
      T(2)=T(2)+QY(IT)*COXIX
      T(3)=T(3)+QT(IT)*SIN(XIX)
8     CONTINUE

      IF (XI.GE.BRAN) GO TO 13
```

```
C SIMPSON RULE
C
        HH=HH/3.
        DO 46 K=1,3
 46     SUM(K)=HH*(R(K)+4.*T(K))
        GO TO 4
C
C Filons formula
C
C
 13     XIH=XI*HH
        XXIH=XI*XIH
        SIX=SIN(XIH)
        COX=COS(XIH)
        C=(SIX/XIH-COX)*4.
        D=XIH+SIX*COX-2.*SIX*SIX/XIH
        E=1.+COX*COX-2.*SIX*COX/XIH
        DO 47 K=1,3
 47     SUM(K)=(D*DIF(K)+E*R(K)+C*T(K))/XXIH
C
C CHECK FOR ACCRACY
C THE END RESULT WAS FOUND TO BE LITTLE AFFECTED EVEN WHEN THIS
C ACCURACY WAS NOT REACHED.
C
 4      IF (NHALF.EQ.1) GO TO 16
        SUMS(1)=SX(LL)+SUM(1)
        SUMS(2)=SY(LL)+SUM(2)
        SUMS(3)=TA(LL)+SUM(3)
C
C Accuracy as compared to the value of the integral between A and B
C
        DO 48 K=1,3
        ABSD(K)=ABS(SUM(K)-SI(K))
        IF (ABSD(K).GT.ABS(DELT*SUM(K))) GO TO 16
 48     CONTINUE
C
        IF (ISTEP.EQ.1) GO TO 17
C
C ACCURACY  AS COMPARED TO THE MAXIMUM LOAD INTENSITY
C
```

```
        DO 49 K=1,3
        IF (ABSD(K).GT.(DELTA*PMAX)) GO TO 16
 49     CONTINUE
        GO TO 17
C
 16     NHALF=N
        N=2*NHALF
        IF (N.LE.IMAX) GO TO 19
        IF (IER.NE.0) GO TO 191
        IER=1
C    The Error Message at this point is supressed to reduce the
C    volume of the out put.
C
C  WRITE ERROR MESSAGE, IF N.GT.IMAX
C
191     continue
        GO TO 17
C
C RENAME FOR NEXT CHECK OF ACCURACY
C
 19     DO 50 K=1,3
        SI(K)=SUM(K)
 50     R(K)=R(K)+2.*T(K)
        GO TO 6
C
 17     SX(LL)=SUMS(1)
        SY(LL)=SUMS(2)
        TA(LL)=SUMS(3)
C
 5      CONTINUE
C
C Stresses in X- and Y- Dirn. not including factor FAC
C
        DO 15 J=1,IY
        ETO=CY(J)
        ETA=1.-ETO
C
        DO 15 I=1,IX
        XI=CX(I)*ZETA
        LL=(I-1)*IY+J
        IF (ETA.NE.1.) GO TO 30
C
C Stresses at the usrface (ETA.EQ.1) not including
C factor FAC. Use modified formula for stresses at the surface.
C
        SX(LL)=SX(LL)-SY(LL)
        SY(LL)=0.
        DO 32 IS=1,L
        ABSAL=ABS(ALPHA(IS))
        IF ((XI/ABSAL)-1.) 33,34,32
 33     SY(LL)=SY(LL)-2.*0.785398163397448*ALPHA(IS)/ABSAL
 34     SY(LL)=SY(LL)-0.785398163397448*ALPHA(IS)/ABSAL
 32     CONTINUE
        SX(LL)=SX(LL)+SY(LL)
        TA(LL)=0.
        GO TO 31
C
C Stresses below the surface (ETA.LT.1) not including
C factor FAC
C
```

```
 30     CALL INTEG (ETA,XI,B,AR)
        SX(LL)=SX(LL)-AR(1)+AR(2)-(3.-ETA)*AR(3)+AR(4)
        SY(LL)=SY(LL)-AR(1)-AR(2)-(1.+ETA)*AR(3)-AR(4)
        TA(LL)=TA(LL)+AR(5)+AR(6)-AR(7)
C
C Stresses in X- and Y- dirn and principal stresses
C Tension is positive
C
 31     SSUM=(SX(LL)+SY(LL))/2.
        SDIF=(SX(LL)-SY(LL))/2.
        ROOT=SQRT(SDIF*SDIF+TA(LL)*TA(LL))
        SX(LL)=FAC*SX(LL)
        SY(LL)=FAC*SY(LL)
        TA(LL)=FAC*TA(LL)
        S1=FAC*(SSUM-ROOT)
        S2=FAC*(SSUM+ROOT)
C
C Compute pore  pressures for plane strain Conditions with
C poissons ratio of 0.5 using skemptons pore pressure parameters
C A and B, herein called ABAR and BBAR.
C CONST was earlier defined as CONST=0.5*(ABAR-1/3)+1/2.
C
        U(LL)=-BBAR*(S2+(S1-S2)*CONST)
 15     CONTINUE
        WRITE (IOUTP,93)
C
C FORMAT STATEMENTS
C
C
 93     FORMAT (//////)
 94     FORMAT (1H ,10X,'THE ACTUAL LOAD IS APPROXIMATED BY ',I3,/
     1    11x,' LOADS OF EQ INTNSTY WHICH EXTEND FROM X=0 TO ALPHA(I)',
     2    1H ,10X,'IF ALPHA(I) IS NEGATIVE, THIS LOAD IS SUBTRACTED',//
C
 95     FORMAT (1H ,15X,'ALPHA(',I2,' ) = ',F10.3,' FEET')
C
C
C
        RETURN
        END
C
C END OF  SUBROUTINE PORE
C BEGIN SUBROUTINE DISP
        SUBROUTINE DISP (U,LI,OMEGA,PHI,T,UAVE,LIFT,MYE,IEND,XT,SV)
C
C
C This subroutine computes the pore pressures at time T by
C treating the consolidation equation as an eigenvalue
C problem.
C U       Pore pressures to be output. For LI=5,6 this vector
C       contains the additional pore pressures for the new load
C       when this subroutine is called.
C LI    Load identifier.
C LI=1  Determination of vectors A and B for the load addition.
C LI=2  Determination of pore pressures due to the stepwise
C       const. loads.
C LI=3  Determination of vectors A and B for times between
C       load application if the soil parameters are variable.
C LI=5  First LIFT , first use of DISP.
C ISP=1 Compute and print the pore pressures at all points of
```

```
C        the solution domain.
C ISP=0 Compute only the average pore pressures at different
C        depths at all IEND points.
C IVAR   identifier for soil parameters
C IVAR=0  Constant soil parameters
C IVAR=1  Variable soil parameters
C PHI     Vector depending on the soil parameters for vert. flow.
C OMEGA   vector depending on the soil parameters fot H-flow.
C T       Time
C LIFT    no. of vectors A and B
C M       Program numbering system, No. of points in Vert. Dirn.
C N       Program numbering system, No. of points in H-dirn.
C Storage reservations are made for 40 horizontal points and
C 6 step loads.
C
        DIMENSION U(1),PHI(1),OMEGA(1),UAVE(1),XT(1),SV(1)
        DIMENSION EIGV(10),EIGX(40),AUX(160),XV(100),XVI(100)
        DIMENSION XH(1600),XHI(1600),FH(500),F(200),A(1200),B(1200)
        DIMENSION VJ(11),RJ(40),RJJ(20),G(280),UBAV(240),UBB(20)
C       DIMENSION W1(300)
C
        EQUIVALENCE (G(1),A(501))
C
        COMMON/ SAPOD/ IOUTP,W,H,GLOAD,CLOAD,NARC,NRAD
        COMMON/ SADI1/ LAYER,IBCV,MHE,M,N,IDC,NDR,ISUM,XET(41)
        COMMON/ SADI2/ FIMPV,RC,RK,C,RO,RE,TA,ISP,IVAR
C
                        ief=64
C
        LIM=LI
        IF (LI.LT.5) GO TO 2
        IF (LAYER.LT.3) LAYER=2
C
C Call MODAL for determination of eigen values, modal matrix and
C inverse of the modal matrix for the case of vertical and
C Hori. flow
C
        CALL MODAL (LAYER,IBCV,M,FIMPV,RC,RK,O.,H,EIGV,XV,XVI,AUX)
C  PAGE 60
        IF (IDC.EQ.1) GO TO 1
        CALL MODAL (1,4,N,FIMPV,RC,RK,RO,RE,EIGX,XH,XHI,AUX)
 1      LIM=1
C
C Determine the diagonal matrices F and FH
C
 2      CALL EFGEN (PHI,T,EIGV,IVAR,IEND,M,F,LI)
        IF (IDC.EQ.1) GO TO 3
        CALL EFGEN (OMEGA,T,EIGX,IVAR,1,N,FH,LI)
C
C BRANCH DEPENDING ON THE VALUE OF LIM
C
 3      GO TO (4,5,6),LIM
C
C LIM=1
C DETERMINE VECTORS A AND B FOR THE LIFT-TH LOAD ADDITION
C ***********************************************************
C
C Determination of  VECTOR B for the LIFT-th load addition
C
 4      IB=(LIFT-1)*M*IEND
```

```
         IE=0
         DO 10 K=1,IEND
         DO 11 I=1,M
         IA=(K-1)*MYE+1
         II=I-M
         IB=IB+1
         IE=IE+1
         B(IB)=0.
         DO 12 J=1,M
         II=II+M
         IA=IA+1
 12      B(IB)=B(IB)+XVI(II)*U(IA)
               do 340 iief=1,ief
 340             B(IB)=B(IB)/F(IE)
 11                continue
 10      CONTINUE
C
         IF (IDC.EQ.1) GO TO 13
C DETERMINE VECTOR A--HORIZONTAL CASE
C
         II=0
         LIN=(LIFT-1)*N+1
         LIN2=LIFT*N
         do 121 I=1,IEND
         UBB(I)=0.
         do 120 J=1,MYE
         II=II+1
         UBB(I)=UBB(I)+U(II)*SV(J)
 120     continue
 121     continue
         call LINT (XET,UBAV,N,LIN2,XT,UBB,IEND)
C To avoid numerical instability put UBAV(I)=0.1 if it is zero.
C
         do 1210 I=LIN,LIN2
               if (ABS(UBAV(I)).LT.0.1) UBAV(I)=0.1
 1210    continue
         IS=(LIFT-1)*N
         DO 14 I=1,N
         IE=0
         II=I-N
         IS=IS+1
         A(IS)=0.
         IA=LIN2+1
         DO 15 J=1,N
         II=II+N
         IA=IA-1
         IE=IE+1
 15      A(IS)=A(IS)+XHI(II)*UBAV(IA)
               do 341 iief=1,ief
341                A(IS)=A(IS)/FH(I)
 14      CONTINUE
C
 13      IF (ISP.EQ.0) RETURN
C LIM=2
C DETERMINE THE PORE PRESSURES AT TIME T AT XT(J),J=1,IEND
C ***********************************************************
C
 5       NM=M
         III=MYE
         DO 50 I=1,ISUM
```

```
 50     U(I)=0.
C
        DO 51 J=1,IEND
C
        RJAVE=1.
        ID=(J-1)*M+1
        IE=(J-1)*N+1
C CONSIDER INFLUENCE OF LIFT LOADS
C
        DO 53 K=1,LIFT
        IB=ID+M*IEND*(K-1)
        CALL MAMULP (XV,F,B,VJ,M,IB,ID)
C
C BRANCH IF VERT FLOW ONLY
C
       IF (IDC.EQ.1) GO TO 54
        IB=1+N*(K-1)

C       goto 54
        CALL MAMULP (XH,FH,A,RJ,N,IB,1)
        do 75 IR=1,N
        RJ(IR)=RJ(IR)/UBAV(K*N+1-IR)
 75     continue
C
         DO 650 IR=1,N/2
         HOLD=RJ(IR)
         RJ(IR)=RJ(N-IR+1)
         RJ(N-IR+1)=HOLD
 650     continue
C
C Determine the average pore pressures at M+1 points in
C vertical direction at XT(J). Include the free drainage at
C  the upper boundary. The result after LIFT cycles of loop 53
C is returned to the calling program. The drainage at the
C lower boundary is considered outside loop 53.
C       CALL LAGR (XT,RJJ,IEND,1,XET,RJ,N)
        call LINT (XT,RJJ,IEND,IEND,XET,RJ,N)
C
 54     II=(J-1)*MYE+1
        U(II)=0.
        DO 57 I=1,M
        II=II+1
        IF (IDC.EQ.1) GO TO 55
        RJAVE=RJJ(J)
        if (RJAVE.LT.0.) RJAVE=0.0
        GO TO 57
 55     RJAVE=1.
 57     U(II)=U(II)+VJ(I)*RJAVE
 53     CONTINUE

        IF (IBCV.EQ.3) GO TO 58
        II=J*MYE
        U(II)=FIMPV*U(II-1)

 58     IF (ISP.EQ.0) GO TO 59
        IF (IDC.EQ.1) GO TO 60

 Output the pore pressures at XT(J) for the case of Vert+ Hor flow

        WRITE (IOUTP,94) T,XT(J)
```

```
          GO TO 62
C
C Output the  pore pressures at XT(J) for the case of Vert flow only
C
 60      WRITE (IOUTP,91) T,XT(J)
 62      II=(J-1)*MYE
         DO 61 I=1,MYE
         II=II+1
 61      WRITE (IOUTP,92) U(II)
         WRITE (IOUTP,93)
         GO TO 59
C
C Compute the ave pore pressures at XT(J)
C
 59      II=(J-1)*MYE
         UAVE(J)=0.
         DO 63 I=1,MYE
         II=II+1
 63      UAVE(J)=UAVE(J)+U(II)*SV(I)
C
 51      CONTINUE
         RETURN
C
C
C Determine vectors A and B for the case of variable soil para-
C meters and times between load applications LIM=3
C *********************************************
C
C Determine vector B
C
 6       II=IEND*M
         IB=0
         DO 20 K=1,LIFT
         DO 20 I=1,II
         IB=IB+1
                 do 20 iief=1,ief
20                 B(IB)=B(IB)*F(I)
C
         IF (IDC.EQ.1) RETURN
C
C DETERMINE VECTOR A
C
         II=N
         IA=0
         DO 22 K=1,LIFT
         DO 22 I=1,II
         IA=IA+1
                do 22 iief=1,ief
22                A(IA)=A(IA)*FH(I)
         RETURN
C
C FORMAT STATEMENTS
C
 91      FORMAT (////,1H ,10X,'T= ',F6.0,' DAYS,X/W= ',F8.3,/
     1    ' PORE PRESSURES IN PSF-VERTICAL FLOW ONLY',//)
 92      FORMAT (1H ,10X,11F10.3)
 93      FORMAT (///)
 94      FORMAT (////,1H ,10X,'T= ',F6.0,' DAYS X/W = ',F8.3,
     1           ' PORE PRESSURES IN PSF DUE TO VERT + HORI FLOW',//)
C
```

```
      END
C
C END OF SUBROUTINE DISP
C
C SUBROUTINE SETL BEGINS
C
      SUBROUTINE SETL (U,SETTL,IEND,KKK,MYE,F,FUP,FLO,KIAV)
C
C This usbroutine computes consol. (F=1) or total (F.GT.1)
C settlements using constant (KIAV=1+IAV=1) or variable KIAV=2
C soil parameters.
C
C U      Vector of dissipated pore pressures with IEND*MYE
C        elements.
C SVM    Modified mathematical molecule for Simpsons or
C        trapezoidal formula (considers case of stratified
C        soil if LAYER.GT.2)
C SETTL  VeCtor of computed settlements with IEND elements
C IEND   No. of settlements
C KKK    No. of distinct pore pressures in the upper layer
C MYE    No. of distinct pore pressures in both layers
C F      Consol. settlements are computed if F=1.0
C        Total settlements are Computed if F=1./B where
C        B= Skempton pore pressure coeff.
C FUP    Parameter for the upper layer which incorporates
C        the soil coeff.
C FLO    Corresponding parameter for the lower layer.
C
      DIMENSION U(1),SETTL(1),SVM(12),P(11),PC(11),PLOG(11)
C
      COMMON/ SACSE/ ROC,ROCL,SVM,P,PC,PLOG,PO,PCO,IAV,IK,ISAT,AAV,AAF
C
       ISE=ISE+1
901    format ('NO. of times entered SETL =',I5)
       write (IOUTP,901) ISE
      R=ROC
      A=FUP
      II=-MYE
      JST=1
      JND=KKK
      JSS=0
C
      DO 1 I=1,IEND
1     SETTL(I)=0.
C
6     DO 2 I=1,IEND
      II=II+MYE
      IU=II
      S=0.
      JS=JSS
C
      DO 3 J=JST,JND
      IU=IU+1
      JS=JS+1
      GO TO (4,5),KIAV
C
C Constant soil parameters IAV=0 KIAV=1
C
4     S=S+F*SVM(JS)*U(IU)
      GO TO 3
```

```
C
C Variable soil parameters IAV=1 KIAV=2
C
 5      PP=P(J)+F*U(IU)
C   if the current effective stress at some point becomes
C   negative then it is put as P(J) at that point.
C   i.e no swelling is considered.
C
        if (PP.LT.P(J)) PP=P(J)
        IF(PP.GT.PC(J)) GO TO 7
        S=S+R*SVM(JS)*ALOG(PP/P(J))
C
C
        GO TO 3
 7      S=S+SVM(JS)*(ALOG(PP/PC(J))+R*PLOG(J))
 3      CONTINUE
        SETTL (I)=SETTL(I)+A*S
 2      CONTINUE
C
C Consol. of the lower layer
C
        IF (JND.EQ.MYE) RETURN
        A=FLO
        R=ROCL
        II=KKK-MYE-1
        JST=KKK
        JND=MYE
        JSS=KKK
        GO TO 6
        END
C
C END OF SETTL
C BEGIN SUROUTINE MAMULP
C
        SUBROUTINE MAMULP (A,D,B,C,N,IS,II)
C
C This subroutine performs the matrix multiplication
C (General matrix A)*(Diagonal matrix D)*(Vector B) = (Vector C)
C All matrices are stored one dimensionally with A having N*N
C elements and D,B,C each having N elements. The first element
C of B and D are B(IS) and D(II)
C
C The formula for the I-th element of C is
C C(I)=SUM(K=1,N) of A(I+(K-1)*N)*B(IS-1+K)*D(II+K-1)
C
        DIMENSION A(1),B(1),C(1),D(1)
C
          ief=64
        do 1 I=1,N
        IA=N*N+I
        IB=IS+N
        ID=II+N
        C(I)=0.
        DO 1 K=1,N
        IB=IB-1
        ID=ID-1
        IA=IA-N
         cc=A(IA)*B(IB)
                 do 20 iief=1,ief
 20            cc=D(ID)*cc
```

```
         C(I)=C(I)+cc
 1       CONTINUE
         RETURN
         END
C
C END OF SUBROUTINE MAMULP
C SUBROUTINES BEGIN HERE.
C
         SUBROUTINE OVERFLO (J)
C
C
         J=1
         RETURN
         END
         SUBROUTINE HDIST (UB, XT, IEND, ICV, CHIN, DXSQ, AAH, MHE, W, XET, IPOR, HF
     *, MYE, POR)
C Begin subroutine  computes the horizontal distance  from the
C center line to the point
C where the pore pressure is 0.1% of the maximum pore
C pressure under the embankment. This is taken to be the Hori. drainage
C distance. This subroutine will be active only once.
         dimension UB(1), XT(1), CHIN(1), XET(1)
         if (HF.eq.0.) goto 100
         if (IPOR.eq.1) goto 100
C Find maximum pore pressure
         do 50 i=1, IEND
         if (umax.lt.UB((i-1)*MYE+1)) umax=UB((i-1)*MYE+1)
 50      continue
         umin=umax*0.001
         i=1
 60      if (UB((i-1)*MYE+1).lt.umin) goto 65
         i=i+1
         if (i.lt.(IEND+1)) goto 60
         POR=1.+(1.-XT(IEND-1)/XT(IEND))*(UB((IEND-1)*MYE+1)-umin)/(UB((
     *IEND-2)*MYE+1)-UB((IEND-1)*MYE+1))
         goto 70
 65    POR=(XT(i-1)+(XT(i)-XT(i-1))*(UB((i-2)*MYE+1)-umin)/(UB((
     1i-2)*MYE+1)-UB((i-1)*MYE+1)))/XT(IEND)
 70      IPOR=1
C
C Redefine horizontal grid points and the related parameters
C using new horizontal drainage distance.
C
         do 529 I=1, ICV
         CHIN(I)=CHIN(I)*DXSQ
 529     continue
         AAH=AAH*DXSQ
         AI=MHE-1.
         DHX=POR*XT(IEND)*W/AI
         do 25 I=1, MHE-1
         XET(I)=POR*(I-1)*XT(IEND)/AI
 25      continue
         DXSQ=DHX*DHX
         AAH=AAH/DXSQ
         do 530 i=1, ICV
         CHIN(i)=CHIN(i)/DXSQ
 530     continue
         write (IATP, 778)POR
 778     format ('NEW POR=', f10.5)
 100       return
```

```
      end
C End of subroutine HDIST
      SUBROUTINE APROX (X,Y,MN,N,D)
C
C This subroutine approximates the actual load by N strips of
C constant thickness D
C
      DIMENSION X(1),Y(1),XA(25),YA(25)
      COMMON/ POAPI/ ALPHA(30),L
C
C
C DETERMINE MAX VALUE OF Y(1)
C
      M=MN
      YMAX=Y(1)
      DO 1 I=2,M
      IF (Y(I).GT.YMAX) YMAX=Y(I)
 1    CONTINUE
C
C Initiate first step starting with X(M) and Y(M)
C
      AN=N
      D=YMAX/AN
      L=1
      H=Y(M)
      XX=X(M)
      XA(1)=0.
C
C Compute the portion between two horizontal lines with distance D
C
 2    YA(1)=H
      K=2
      XA(K)=XX
      YA(K)=H
      H=H+D
C
C If statement because of possible truncation error
C
      IF (ABS(H-YMAX).LT.0.001) H=YMAX
 3    MM=M-1
      IF (MM.EQ.0) GO TO 4
      XX=(X(M)-X(MM))*(H-Y(MM))
C     IF (ABS(Y(M)-Y(MM)).LT.0.01) J=1
      IF (ABS(Y(M)-Y(MM)).LT.0.01) CALL OVERFLO (J)
      IF (ABS(Y(M)-Y(MM)).LT.0.01) GO TO 61
      XX=XX/(Y(M)-Y(MM))
C
C If the denominator approaches zero, J is set equal to 1
C
 61   IF (J.NE.1) GO TO 5
 6    K=K+1
      J=0
      XA(K)=X(MM)
      YA(K)=Y(MM)
      M=MM
      GO TO 3
 5    XX=XX+X(MM)
      IF (ABS(XX-X(MM)).LT.0.001) GO TO 8
      IF (XX.LT.X(MM)) GO TO 6
      MM=M
```

```
      GO TO 9
 8    M=MM
C
 9    K=K+1
      XA(K)=XX
      YA(K)=H
 4    XA(K+1)=0.
      YA(K+1)=H
      A=0.
      DO 10 I=1,K
      J=I+1
      A=A+XA(I)*YA(J)-YA(I)*XA(J)
 10   CONTINUE
C
C Determine width of constant load equivalent to portion between
C two horizontal lines with distance D.
C ALPHA is negative if this portion is to be subtracted.
      ALPHA(L)=A/(2.*ABS(D))
      IF (L.EQ.N) GO TO 11
 13   IF (ALPHA(L).EQ.0.) L=L-1
      IF (MM.EQ.0) GO TO 12
      L=L+1
      GO TO 2
 11   IF (YMAX.LE.Y(1)) GO TO 12
      D=-1.*D
      GO TO 13
 12   D=ABS(D)
      RETURN
      END
C
C
C
C
C
C SUBROUTINE DETFS
      SUBROUTINE DETFS (XC,YC,R,XINP,YINP,MINP,MX,MYE,SU,FS)
C
C This subroutine determines the factor of safety against failure
C along a circular arc by taking the ratio of the resisting and
C driving moments about the center of the arc. Shear strengths
C along that part of the arc, which passes through the subsoil
C are obtained by interpolating between the elements of vector SU.
C This is an analysis in terms of TOTAL STRESSES.
C
      DIMENSION XINP(1),YINP(1),SU(1),XS(22),YS(22),X(2)
      DIMENSION WWW(2),XAUX(10),YAUX(10),SINUS(2),COSIN(2)
C
      REAL MD,MR
C
      COMMON/ INDET/ RHO(19),TAU(19),PSI(19)
      COMMON/ SAPOD/ IOUTP,W,H,GLOAD,CLOAD,NARC,NRAD
      COMMON/ SADET/ XSTAB(51),YSTAB(11),DX,DY,YWM,TGPHI
C
C STATEMENT FUNCTIONS
C
      FUNA(A,B)  =(XC+A*AA)/B
      FUNB(B)    =AB*AB+(RX-AA*AA)/B
      FUNC(A,B,C)=A+B*(C-A)
C
C The parameters have the following significance
```

```
C XC,YC coord of the center of the arc.
C R      radius of the arc
C XINP,YINP  Coord of the points describing the X-section of
C        the embankment.
C MINP   No. of points XINP/YINP
C MX     No. of equally spaced points in X-dirn.
C MYE    No. of equally spaced points in Y-dirn.
C SU     Vector of shear strengths with MX*MYE elements
C FS     Factor of safety
C RHO(I) Slope of the line connecting XINP(I)/YINP(I) and
C        XINP(I+1)/YINP(I+1)
C PSI(I) YINP value of the above line for XINP=0.
C TAU(I) TAU(I)=1.+RHO(I)*RHO(I)
C GLOAD  unit weight of the embankment soil
C CLOAD  Shear strength of the embankment soil
C XSTAB  MX equally spaced points in X-dirn.
C YSTAB  MYE equally space points in Y-dirn.
C DX,DY  Intervals in X- and Y-dirn.
C NARC   One-half no. of subarcs within subsoil
C
C
      ANARC=2*NARC
      MXM=MX-2
      RR=R*R
      XX=XC*XC
      RX=RR-XX
      YY=YC*YC
      LAST=0
C
C POINTS OF INTERSECTION BETWEEN ARC AND SURFACE
C
      AA=SQRT(RR-YY)
C
C
      XS(1)=XC-AA
      XG=XC+AA
      IF (XG.GE.XINP(MINP)) LAST=1
C
C POINT OF INTERSECTION BETWEEN ARC AND EMBANKMENT SURFACE
C
      I=0
      J=2
 1    I=I+1
      AA=YC-PSI(I)
      AB=FUNA(RHO(I),TAU(I))
      AA=FUNB(TAU(I))
      IF (AA.LT.0.) GO TO 1
      AA=SQRT(AA)
      XT=AB-AA
      IF (XT.GE.XINP(I+1)) GO TO 1
      XS(2)=XT
      YS(2)=XT*RHO(I)+PSI(I)
C
C Resisting moment MR due to the arc between XS(1)/YS(1)=0. and
C XS(2)/YS(2) within the embankment. Driving moment MD due to
C the segment between XS(1)/0. and XS(2)/YS(2).
C
      BETA1=0.5*ASIN(YC/R)
      BETA2=0.5*ASIN((YC-YS(2))/R)
      MR=2.*RR*CLOAD*(BETA1-BETA2)
```

```
        A=XS(1)-XS(2)
                 A=SQRT(A*A+YS(2)*YS(2))
        MD=(A*A*A*COS(BETA1+BETA2))/2.
        IF (LAST.EQ.0) GO TO 2
C
C THE POINTS XS/YS ARE EQUAL TO THE POINT S XINP/YINP
C
        I=I+1
        DO 3 K=I,MINP
        J=J+1
        XS(J)=XINP(K)
 3      YS(J)=YINP(K)
 31     LAST=J
        GO TO 7
C
C Determine the second point of intersection between the arc and the
C embankment surface. Store all points in XS/YS which lie between
C this point and the point XS(2)/YS(2).
C
 2      XT=AB+AA
        IF (XT.LE.XINP(I+1)) GO TO 4
 5      I=I+1
        J=J+1
        XS(J)=XINP(I)
        YS(J)=YINP(I)
        IF (I.EQ.MINP) GO TO 31
        IF (XINP(I+1).GT.XG) GO TO 6
        IF (YINP(I+1).LT.YC) GO TO 5
 6      AA=YC-PSI(I)
        AB=FUNA(RHO(I),TAU(I))
        AA=FUNB(TAU(I))
        AA=SQRT(AA)
C
        GO TO 2
 4      J=J+1
        XS(J)=XT
        YS(J)=XT*RHO(I)+PSI(I)
C
C Resisting and driving moments due to the arc and the segment
C between the points XS(J)/YS(J) and XG/O.
C
        BETA2=0.5*ASIN((YC-YS(J))/R)
        LAST=J+1
        XS(LAST)=XG
        YS(LAST)=0.
        MR=MR+2.*RR*CLOAD*(BETA1-BETA2)
        A=XG-XS(J)
        A=SQRT(A*A+YS(J)*YS(J))
        MD=MD-(A*A*A*COS(BETA1+BETA2))/2.
C
C DRIVING MOMENTS DUE TO TRIANGLES WITH ONE APEX AT XS(1)/O.
C
 7      XX=3.*XC-XS(1)
        DO 8 I=3,LAST
        J=I-1
        A=XS(1)*(YS(I)-YS(J))-XS(J)*YS(I)+XS(I)*YS(J)
        MD=MD+(XX-XS(J)-XS(I))*A
 8      CONTINUE
C
C RESISTING MOMENT DUE TO THE PART OF THE ARC WHICH PASSES THROUGH
```

```
C TH SUBSOIL
C
         IF (H.EQ.O.) GO TO 100
         IF (MYE.EQ.1) GO TO 20
C
C Resisting moment along subarcs in the subsoil. The shear
C strengths along the 2*NARC) subarcs are assumed const and
C obtained by linear interpolation between the appropriate
C values of SU.
C
        DARC=(3.1415927-4.*BETA1)/ANARC
        RARC=RR*DARC
        BETA=2.*BETA1-DARC/2.
        DO 9 L=1,NARC
        BETA=BETA+DARC
        A=R*COS(BETA)
        X(1)=XC-A
        X(2)=XC+A
        A=R*SIN(BETA)-YC
        AJ=A/DY+1.
        J=AJ
        FY=(A-YSTAB(J))/DY
C
        DO 10 K=1,2
        AII=X(K)/DX
        I=AII
        IF (I.LE.MXM) GO TO 11
C
C Midpoint of the subarc lies outside the domain for which
C SU-s are specified. Interpolation is done in Y-dirn only
C between the values SU(MX*(MYE-1)+1) through SU (MX*MYE).
C
        IJ=J+(MX-1)*MYE
        JJ=IJ+1
        AA=SU(IJ)
        AB=SU(JJ)
        GO TO 12
C
C Interpolation for the midpoint of the subarc. Two linear
C interpolation are performed in X-dirn, One linear interp-
C olation is performed in Y-dirn between the values obtained.
C
 11     IJ=J+I*MYE
        JJ=IJ+MYE
        I=I+1
        FX=(X(K)-XSTAB(I))/DX
        AA=FUNC(SU(IJ),FX,SU(JJ))
        IJ=IJ+1
        JJ=JJ+1
        AB=FUNC(SU(IJ),FX,SU(JJ))
 12     MR=MR+RARC*FUNC(AA,FY,AB)
 10     CONTINUE
        DM=MD*GLOAD/6.
 9      CONTINUE
        GO TO 100
 20     RARC=RR*(3.1415927-4.*BETA1)
        MR=MR+SU(1)*RARC
C
C   Factor of safety.
C
```

```
 100    MD=MD*GLOAD/6.
C
C IF THERE IS AN OVERFLOW CONDITION, J IS SET .EQ. 1 AND
C FS IS SET .EQ. 1.0E50
C
        JJJ=0
        IF (MD.LT.0.0000000000000001) CALL OVERFLO (JJJ)
        IF (MD.LT.0.0000000000000001) GO TO 111
        FS=MR/MD
 111    IF (JJJ.NE.1) GO TO 40
        FS=100.
        JJJ=0
        RETURN
C
C Determination of the resisting moment due to friction.
C
 40     IF (YWM.EQ.0.) RETURN
        IF (FS.LT.0.0001) FS=1.
        FAC=TGPHI/FS
        RMR=MR
        KOUNT=1
        XAUX(1)=XS(1)
        YAUX(1)=0.
        AB=YC-YWM
        AB=SQRT(RR-AB*AB)
        XAUX(2)=XC-AB
        YAUX(2)=YWM
        IF (XAUX(2).GE.XS(2))  GO TO 41
        XAUX(2)=XS(2)
        YAUX(2)=YS(2)
 41     BETA2=0.5*ASIN((YC-YAUX(2))/R)
        XAUX(3)=XAUX(2)
        K=3
        I=1
 43     I=I+1
 42     IF (XAUX(K)-XINP(I)) 44,45,43
 45     YAUX(K)=YINP(I)
        GO TO 46
 44     YAUX(K)=RHO(I-1)*XAUX(K)+PSI(I-1)
 46     K=K+1
        IF (XAUX(1).LE.XINP(I)) GO TO 47
        XAUX(K)=XINP(I)
        YAUX(K)=YINP(I)
        I=I+1
        GO TO 46
 47     XAUX(K)=XAUX(1)
        YAUX(K)=RHO(I-1)*XAUX(1)+PSI(I-1)
        XAUX(K+1)=XAUX(1)
        YAUX(K+1)=YAUX(1)
        WW=0.
        DO 48 J=1,K
        L=J+1
        WW=WW-XAUX(J)*YAUX(L)+YAUX(J)*XAUX(L)
 48     CONTINUE
        WWW(KOUNT)=WW*GLOAD/2.
        AA=XAUX(1)-XAUX(2)
        BB=YAUX(2)-YAUX(1)
        CC=SQRT(AA*AA+BB*BB)
        SINUS(KOUNT)=BB/CC
        COSIN(KOUNT)=AA/CC
```

```
      RMR=RMR-2.*RR*CLOAD*(BETA1-BETA2)
      IF (KOUNT.EQ.2) GO TO 49
      IF (XS(LAST).EQ.XINP(MINP)) GO TO 49
      KOUNT=2
      XAUX(1)=XC+AB
      YAUX(1)=YWM
      IF (XAUX(1).LE.XS(LAST-1)) GO TO 50
      XAUX(1)=XS(LAST-1)
      YAUX(1)=YS(LAST-1)
 50   BETA2=0.5*ASIN((YC-YAUX(1))/R)
      XAUX(2)=XS(LAST)
      YAUX(2)=0.
      XAUX(3)=XAUX(2)
      K=3
      GO TO 42
C ITERATION FOR THE CORRECT FACTOR SAFETY
C
 49   MR=RMR
      DO 51 I=1,KOUNT
      MR=MR+FAC*WWW(KOUNT)*R/(COSIN(KOUNT)+FAC*SINUS(KOUNT))
 51   CONTINUE
      FSOLD=FS
      FS=MR/MD
      IF (ABS(FS-FSOLD).LT.0.001) RETURN
      FAC=TGPHI/FS
      GO TO 49
      END
C END OF SUBROUTINE DETFS
C
C BEGIN SUBROUTINE GAIN
C
      SUBROUTINE GAIN (UA,R,SU,MYE,MXT,MXE,MX,NIM,CO,CP,III)
C
C This subroutine determines the shear strengths at MX*MYE points
C XE/YE from a knowledge of the initial shear strengths CO and
C the C/PBar=CP-ratios
C
C UA    Dissipated pore pressures at XT/YE
C R     Auxiliary matrix for the computation of the dissipated pore
C       pressures at XT/YE from those at XT/YE
C SU    Shear strengths at XE/YE. SU(XE/YE) is equal to the initial
C       shear strength CO(YE) plus the product of the dissipated
C       pore pressure at XE/YE and the C/PBar-ratio CP(YE)
C MYE   No. of points YE in vertical direction.
C NIM   No. of intervals in horizontal Dirn.
C MXT   NIM numbers of points XT in each interval.
C MXE   NIM no. of points in XE in each interval
C MX    Total no.of points XE
C CP    Vector of MYE C/PBAR-ratios
C CO    Vector of MYE initial shear strengths
C III   Index for the identification of the following cases--
C       If III=1, all elements of UA are  assumed to be zero.
C       If III=0, some or all elements of UA are not equal to zero
C
      DIMENSION UA(1),R(1),SU(1),MXT(1),MXE(1),CO(1),CP(1)
C
      K=0
      IF (III.EQ.0) GO TO 1
C
C ALL ELEMENTS OF UA ARE EQUAL TO ZERO
```

```
C
        DO 2 I=1,MX
        DO 2 J=1,MYE
        K=K+1
        SU(K)=CO(J)
 2      CONTINUE
        RETURN
C
C The shear strength consists of the initial strength plus some
C gain due to dissipated pore pressures
C
 1      IUBE=0
        IUND=0
        IRND=0
        DO 3 JJ=1,NIM
        IUBS=IUBE+1
        IUBE=IUBE+MYE*MXT(JJ)
        IUST=IUND+1
        IUND=IUND+MYE*MXE(JJ)
        IRST=IRND+1
        IRND=IRND+MXT(JJ)*MXE(JJ)
        CALL MPRD (UA,R,SU,MYE,MXT(JJ),MXE(JJ),IUBS,IRST,IUST)
 3      CONTINUE
C
        DO 4 I=1,MX
        DO 4 J=1,MYE
        K=K+1
        SU(K)=CO(J)+SU(K)*CP(J)
C
 4      CONTINUE
        RETURN
        END
C
C END OF SUBROUTINE GAIN
C
C
C BEGIN SUBROUTINE GENER
C
        SUBROUTINE GENER (P,F,X,N)
C
```

```
C   This subroutine generates the N+1 Coeff. of the characteristic
C   equation of the tridiagonal matrix P
C   The coeff. are stored in vector A. P must be supplied as a one-
C   dimensional array with 2*N elements. An auxiliary vector F with
C   ((N+1)*(N+4)/2-2) elements is used for computation. Vector X
C   contains the N roots of the characteristic equation.
C
        DIMENSION P(1),A(25),F(2),X(1)
C
        IC=0
        F(1)=0.
        F(2)=1.0
        IF=2
        NF=N
C
C COMPUTE F(3) THRU F(N+2)
C
        DO 1 I=1,NF
        IF =IF+1
        IP=2*I
        F(IF)=P(IP-1)*F(IF-2)+P(IP)*F(IF-1)
 1      CONTINUE
C
 4      IC=IC+1
        A(IC)=F(IF)
        IF(IC.EQ.N) GO TO 3
        NF=NF-1
C
C COMPUTE F(N+3) THRU F((N+1)*(N+4)/2-2)
C
        F(IF+1)=0.
        IF=IF+2
        II=IF-NF-3
        IP=2*IC
        F(IF)=1.
        DO 2 I=1,NF
        IF=IF+1
        II=II+1
        IP=IP+2
        F(IF)=P(IP-1)*F(IF-2)+P(IP)*F(IF-1)+F(II)
 2      CONTINUE
        GO TO 4
C
 3      A(IC+1)=1.
C
C CALL RROOT FOR DETERMINATION OF THE REAL ROOTS
C
        CALL RROOT (A,X,N)
C
        RETURN
        END
C
C END OF SUBROUTINE GENER
C BEGIN SUBROUTINE GENS
C
        SUBROUTINE GENS (S,M)
C
C This subroutine generates the mathematical molecule for the
C extended simpsons (1/3) rule or the extended trapezoidal
C rule. Each element is divided by the total length of the
```

```
C integration interval, thus making it only dependent on the
C number (M-1) of subintervals.
C
      DIMENSION S(1)
C
      IF (M.LE.1) RETURN
      MM=M-1
      FAC=MM
      IF (M.EQ.(M/2)*2) GO TO 3
C
C SIMPSON-S RULE IF M IS ODD
C
      FAC=1./(3.*FAC)
      I=1
      S(1)=FAC
 1    I=I+1
      S(I)=4.*FAC
      I=I+1
      S(I)=FAC
      IF (I.EQ.M) RETURN
      S(I)=2.*FAC
      GO TO 1
C
C TRAPEZOIDAL RULE IF M IS EVEN
C
 3    FAC=1./FAC
      S(1)=FAC/2.
      S(M)=FAC/2.
      IF (MM.LT.2) RETURN
      DO 4 I=2,MM
 4    S(I)=FAC
      RETURN
      END
C
C END OF SUBROUTINE GENS
C
C BEGIN SUBROUTINE  INIT
C
C
C
      SUBROUTINE INIT (XINP,YINP,MINP,XC,YC,YY,ZZ,DMIN)
C
C This subroutine selects starting values for the variables XC/YC
C If Xc -as input- is equal to zero. In addition, three vectors
C are generated which are needed in subroutine DETFS.
C
C XINP,YINP   Coord of the embankment X-section
C MINP        No. of Coord points XINP/YINP
C Xc,YC       Coord of the center of the arc
C DMIN        Minimum increment for the variables XC,YC and R
C YY          Minimum value for YC
C ZZ          Distance below max YINP down to which YC is permissible
C H           Thickness of the compressible layer
C RHO(I)      Slope of the line connecting XINP(I)/YINP(I) and
C             XINP(I+1)/YINP(I+1)
C TAU         TAU=1.+RHO**2
C PSI(I)      YINP-value of the above line for XINP=0
C
      DIMENSION XINP(1),YINP(1)
C
      COMMON/ SAPOD/ IOUTP,W,H,GLOAD,CLOAD,NARC,NRAD
```

```
      COMMON/ INDET/ RHO(19),TAU(19),PSI(19)
C
      XX=XINP(MINP)-DMIN
      YY=YINP(1)
      DO 1 I=2,MINP
      J=I-1
      RHO(J)=(YINP(I)-YINP(J))/(XINP(I)-XINP(J))
      TAU(J)=1.+RHO(J)*RHO(J)
      PSI(J)=YINP(J)-RHO(J)*XINP(J)
      IF (YINP(J).GT.YY) YY=YINP(I)
 1    CONTINUE
      YY=YY-ZZ
      IF (XC.NE.0.) GO TO 2
      YC=YY
      R=YY+H
      A=YY-YINP(1)
      RR=R*R
      XC=(XX+SQRT(RR-YY*YY)+SQRT(RR-A*A))/2.
 2    RETURN
      END
C
C END OF SUBROUTINE INIT
C
C
C
C
C BEGIN SUBROUTINE LAGR
C
      SUBROUTINE LAGR (X,Y,M,JST,XX,YY,N)
C
C This subroutine interpolates the values of the function Y(X)
C from the knpwn YY(XX) by use of Lagrangian polynomial
C
C X   Vector of arguements for which the values of the function are
C     interpolated
C Y   VeCtor of interpolated values starting with Y(JST)
C M   No. of X-s
C XX  Vector of arguements for which the values of the function
C     are known
C YY  Vector of known valuea of the function
C N   No. of xx-s
C RN  Auxiliary vector
C

      DIMENSION X(1),Y(1),XX(1),YY(1),RN(101)
C
      JS=JST-1
      DO 1 J=1,M
      JJ=JS+J
 1    Y(JJ)=0.
C
      DO 3 K=1,N
      DO 4 J=1,M
 4    RN(J)=1.
      RD=1.
C
      DO 2 I=1,N
      IF (I.EQ.K) GO TO 2
      DO 5 J=1,M
 5    RN(J)=RN(J)*(X(J)-XX(I))
```

```
      RD=RD*(XX(K)-XX(I))
2     CONTINUE
      RD=YY(K)/RD
      DO 6 J=1,M
      JJ=JS+J
6     Y(JJ)=Y(JJ)+RN(J)*RD
3     CONTINUE
C
      RETURN
      END
C
C END OF LAGR
C
C
C
C
C
C
C
C
C BEGIN SUBROUTINE MATR
C
      SUBROUTINE MATR (IS,IE,M,XV,A,XM)
C
C Given the vector XV with elements XV(IS),XV(IS+1),...XV(IE), this
C subroutine generates the M by IE=IS+1 matrix XM, whose elements
C are stored one dimensionally as follows--
C XM(1)=1.,XM(2)=(XV(IS)-A),XM(3)=(XV(IS)-A)**2,....XM(M)=
C (XV(IS)-A)**(M-1), XM(M+1)=1.,XM(M+2)=(XV(IS+1)-A),...
C XM(M*(IE-IS+1))=(XV(IE)-A)**(M-1)
C Subtraction of A is done to increase the accuracy.
C
      DIMENSION XV(1),XM(1)
C
      K=0
      DO 1 I=IS,IE
      K=K+1
      XM(K)=1.
      XVT=XV(I)-A
C
C IF STATEMENT TO INCLUDE CASE M=1
C
      IF (M.EQ.1) GO TO 1
      DO 2 J=2,M
      L=K
      K=K+1
2     XM(K)=XM(L)*XVT
1     CONTINUE
      RETURN
      END
C
C END OF MATR
C
C
C begin subroutine minv
C
      SUBROUTINE MINV (A,N,D)
C
C This subroutine inverts a general matrix A by means of the standard
C Gauss-Jordan method.
C
      DIMENSION A(1),L(1600),M(1600)
```

```
C
C SEARCH THE LARGEST ELEMENT
C
          D=1.0
          NK=-N
          DO 80 K=1,N
          NK=NK+N
          L(K)=K
          M(K)=K
          KK=NK+K
          BIGA=A(KK)
          DO 20 J=K,N
          IZ=N*(J-1)
          DO 20 I=K,N
          IJ=IZ+I
 10       IF (ABS(BIGA)-ABS(A(IJ))) 15,20,20
 15       BIGA=A(IJ)
          L(K)=I
          M(K)=J
 20       CONTINUE
C
C INTERCHANGE ROWS
C
          J=L(K)
          IF (J-K) 35,35,25
 25       KI=K-N
          DO 30 I=1,N
          KI=KI+N
          HOLD=-A(KI)
          JI=KI-K+J
          A(KI)=A(JI)
 30       A(JI)=HOLD
C
C INTERCHANGE COLUMNS
C
 35       I=M(K)
          IF (I-K) 45,45,38
 38       JP=N*(I-1)
          DO 40 J=1,N
          JK=NK+J
          JI=JP+J
          HOLD=-A(JK)
          A(JK)=A(JI)
 40       A(JI)=HOLD
C
C Divide column by minus pivot (value of pivot element is
C contained in BIGA)
C
 45       IF (BIGA) 48,46,48
 46       D=0.0
          RETURN
C PAGE P-80
C
 48       DO 55 I=1,N
          IF (I-K) 50,55,50
 50       IK=NK+I
          A(IK)=A(IK)/(-BIGA)
 55       CONTINUE
C
C REDUCE MATRIX
```

```
C
      DO 65 I=1,N
      IK=NK+I
      IJ=I-N
      DO 65 J=1,N
      IJ=IJ+N
      IF (I-K) 60,65,60
60    IF (J-K) 62,65,62
62    KJ=IJ-I+K
      A(IJ)=A(IK)*A(KJ)+A(IJ)
65    CONTINUE
C
C DIVIDE ROW BY PIVOT
C
      KJ=K-N
      DO 75 J=1,N
      KJ=KJ+N
      IF (J-K) 70,75,70
70    A(KJ)=A(KJ)/BIGA
75    CONTINUE

 PRODUCT OF PIVOTS

      D=D*BIGA

 REPLACE PIVOT BY RECIPROCAL

      A(KK)=1.0/BIGA
80    CONTINUE

 FINAL ROW AND COLUMN INTERCHANGE

      K=N
100   K=K-1
      IF (K) 150,150,105
105   I=L(K)
      IF (I-K) 120,120,108
108   JQ=N*(K-1)
      JR=N*(I-1)
      DO 110 J=1,N
      JK=JQ+J
      HOLD=A(JK)
      JI=JR+J
      A(JK)=-A(JI)
110   A(JI)=HOLD
120   J=M(K)
      IF (J-K) 100,100,125
125   KI=K-N
      DO 130 I=1,N
      KI=KI+N
      HOLD=A(KI)
      JI=KI-K+J
      A(KI)=-A(JI)
130   A(JI)=HOLD
      GO TO 100
150   RETURN
      END

 END OF SUBROUTINE MINV
```

```
C
C BEGIN SUBROUTINE MODAL
C
      SUBROUTINE MODAL (LAYER,IBC,N,FIMP,RC,RK,XO,XE,EIG,X,XI,F)
C
C This subroutine generates the coeff. matrix P, determines the
C characteristic equation which is then solved to give the eigen
C values EIG. knowing the eigenvalues, the modal matrix X is
C computed to generate its inverse XI. Generation of P depends
C on the boub ndary conditions which are indicated by LAYER,IBC
C CHI,RC,RK,XOand XE
C
C LAYER      Index for identifiaction of drainage condition and
C            layer interface if any.
C LAYER=1    Hori Drainage
C LAYER=2    Vert. drainage, homogeneous soil
C LAYER.GE.4 -Vert. drainage, two layers where layer gives
C            the location of the interface.
C IBC        Index for identification of boundary conditions
C IBC=1      Vert. drainage- Impeded drainage at bottom
C IBC=2      Vert. drainage- Free drainage at bottom
C IBC=3    Vert. drainage- No drainage at bottom
C FIMP     Impeded drainage factor
C RC       Ratio of coeff. of consol. (Lower/upper layer)
C RK       Ratio of coeff. of permeability (lower/upper layer)
C XO       Lower boundary of the solution domain.  XO=0. if LAYER.GT.1
C XE       Upper boundary of the solution domain.  XE=H if LAYER.GT.1
C EIG      Vector of eigenvalues
C X        Modal matrix=Matrix of eigenvectors
C XI       Inverse of X
C D,F      Auxiliary matrices
C P        Coeff. matrix
C N        No. of eigenvalues=No.of Nodal points in the program
C          numbering system.
C
      DIMENSION P(100),D(50),F(1),EIG(1),X(1),XI(1)
C
C
      IF (IBC.EQ.4) GO TO 25
      IF (LAYER.NE.2) GO TO 1
      IF (IBC.NE.2) GO TO 2
C
C COMPUTE EIGEN VALUES AND MODAL MATRIX DIRECTLY FOR LAYER=2
C AND IBC=2
C
      AN=N+1
      AN=3.141592653589793/AN
      KJ=0
      DO 3 J=1,N
      AJ=J
      EIG(J)=-2.+2.*COS(AJ*AN)
C
      DO 3 K=1,N
      KJ=KJ+1
      AK=K
      X(KJ)=SIN(AK*AJ*AN)
 3    CONTINUE
      GO TO 4
C
C
```

```
2       IF (IBC.NE.3) GO TO 1
C
C COMPUTE EIGEN VALUES AND MODAL MATRIX DIRECTLY FOR LAYER=2
C AND IBC=3
C
        AN=2*N
        AN=3.141592653589793/AN
        KJ=0
C
        DO 5 J=1,N
        AJ=2*J-1
        EIG(J)=-2.+2.*COS(AJ*AN)
C
        DO 5 K=1,N
        KJ=KJ+1
        AK=K
        X(KJ)=SIN(AK*AJ*AN)
5       CONTINUE
        GO TO 4
C
C GENERATE MATRICES P AND D FOR CASES WHERE 2.NE.IBC.NE.3
C
1       D(1)=1.0
        P(1)=0.0
        P(2)=2.0
        IF (IBC.LT.4) GO TO 6
C
C CASE OF HORIZONTAL FLOW
C
25      AN=2*N
        AN=3.141592653589793/AN
        KJ=0

        DO 7 J=1,N
        AJ=2*J-1
        EIG(J)=-2.+2.*COS(AJ*AN)

        DO 7 K=1,N
        KJ=KJ+1
        AK=K
        X(KJ)=SIN(AK*AJ*AN)
7       CONTINUE
        GO TO 4


 GENERATE P AND D FOR VERTICAL DRAINAGE

6       INT=N
        IF (LAYER.GT.2) INT=LAYER-2
        IF (LAYER.EQ.3) I=1
        GO TO 27


        DO 9 I=2,INT
        IE=2*I
        P(IE-1)=-1.
        P(IE)=2.
        D(I)=1.
9       CONTINUE
```

```
      IF (INT.NE.N) GO TO 10
      P(IE)=2.-FIMP
      GO TO 8
C
C
C COEFFICIENTS OF P AND D FOR THE LAYERED CASE
C
 10   PO=-RC*RC
      PE=2.*RC
      FIN=PE/(RC+RK)
      P(IE+1)=-FIN
      P(IE+2)=FIN*(1.+RK)
      D(INT+1)=FIN
      P(IE+3)=-FIN*RC*RK
      P(IE+4)=PE
      D(INT+2)=FIN*RC
      INT=INT+3
C
      DO 11 I=INT,N
      IE=2*I
      P(IE-1)=PO
      P(IE)=PE
      D(I)=RC*D(I-1)
 11   CONTINUE
C
      IF (IBCV.NE.3) GO TO 12
      P(IE-1)=2.*PO
      D(N)=2.*D(N)
      GO TO 8
C
 12   IF (IBCV.EQ.1) P(IE)=RC*(2.-FIMP)
C
C Call GENER to generate the characteristic equtaion and to compute
C the eigen values EIG
C
 8    CALL GENER (P,F,EIG,N)
C
C Compute eigenvectors from P,D and EIG
C
      MEND=N-1
      NN=2*N
      DO 15 K=1,N
      NK=N*K
      X(NK)=1.
      X(NK-1)=P(NN)+EIG(K)
 15   CONTINUE
C
      DO 16 ME=2,MEND
      NN=NN-2
      DO 16 K=1,N
      NK=N*K-ME
      X(NK)=P(NN+1)*X(NK+2)+(P(NN)+EIG(K))*X(NK+1)
 16   CONTINUE
C
C Premultiply matrix X by matrix D
C Restore the X-elements since MINV destroys the original matrix
C
      I=0
      DO 20 J=1,N
      DO 20 K=1,N
```

```
      I=I+1
20    X(I)=X(I)*D(K)
4     NN=N*N
      DO 17 I=1,NN
      XI(I)=X(I)
17    CONTINUE
C
C CALL MINV FOR INVERSION
C
      CALL MINV (XI,N,DET)
C
      RETURN
      END
C
C END OF  SUBROUTINE MODAL
C
C SUBROUTINE MPRD BEGINS
C
      SUBROUTINE MPRD (A,B,R,N,M,L,IAS,IBS,IRS)
C
C This subroutine premultiplies the M*L matrix B by the N*M
C matrix A and stores the result in the N*L matrix R. The first
C elements of the matrices are A(IAS),B(IBS),R(IRS). The normal
C case will be that where IAS=IBS=IRS=1. If all matrices are
C stored one dimensionally, the following formula for the element
C R(IR) is obtained--- R(IR)=R(J+(K-1)*N+IRS-1)=SUM(I=1,M) of
C A(J+(I-1)*N+IAS-1)*B(I+(K-1)*M+IBS-1)
C
      DIMENSION A(1),B(1),R(1)
C
      IR=IRS-1
      KM=IBS-M-1
      DO 1 K=1,L
      KM=KM+M
      DO 1 J=1,N
      IR=IR+1
      IA=J+IAS-N-1
      IB=KM
      R(IR)=0.
      DO 1 I=1,M
      IA=IA+N
      IB=IB+1
      R(IR)=R(IR)+A(IA)*B(IB)
1     CONTINUE
      RETURN
      END
C
C END OF MPRD
C
C BEGIN RROOT
C
      SUBROUTINE RROOT (COF,XR,M)
C
C This subroutine computes the real roots of an M-th degree
C polynomial. COF is the coeff. vector with M+1 elements.
C XR is the vector containing the M roots. M must be
C greater than 2 but less than 50 because of stotage
C allocation. The polynomial has the form F(X)=0.=
C COF(1)+COF(2)*X+......+COF(M+1)*X**M
C A,B,C are auxiliary vectors of length M+1
```

```
C EPS gives the required accuracy.
C
      DIMENSION COF(1),XR(1),A(50),B(50),C(50)
C
      EPS=1./1000.
      N=M
      NN=M+1
      X=0.
C
C Rename original coeff. for final iteration.
C
      DO 1 J=1,NN
      A(J)=COF(J)
 1    CONTINUE
C
C Apply newtons rule X(J+1)=X(J)-FX(X(J))/((D?DX)(F(XJ))
C and obtain the values of the function and its derivative
C for the guess X(J) from HOrners scheme. The roots are
C always approximated from above and the last root is used
C as initial guess for the reduced polynomial.
C
 2    B(NN)=A(NN)
      C(NN)=A(NN)
 4    I=NN
C
      DO 3 J=2,N
      I=I-1
      B(I)=A(I)+X*B(I+1)
      C(I)=B(I)+X*C(I+1)
 3    CONTINUE
      B(1)=A(1)+X*B(2)
C
C Newtons rule and accuracy check
C
      DX=-B(1)/C(2)
      X=X+DX
      EPAB=EPS*ABS(X)
      IF (ABS(DX).GT.EPAB) GO TO 4
      XR(N)=X
C
C Define coeff. of the reduced polynomial.
C
      DO 6 J=1,N
      A(J)=B(J+1)
 6    CONTINUE
      NN=N
      N=N-1
      IF (N.GT.1) GO TO 2
      XR(1)=-A(1)/A(2)
C
C The roots are now stored as XR(1).LT.XR(2).LT. .... LT.XR(M)
C Make the final iteration using the original polynomial
C
      MM=M-1
      DO 7 K=1,MM
 9    I=M+1
      DO 8 J=2,M
      I=I-1
      B(I)=COF(I)+XR(K)*B(I+1)
      C(I)=B(I)+XR(K)*C(I+1)
```

```
8       CONTINUE
C
        B(1)=COF(1)+XR(K)*B(2)
        DX=-B(1)/C(2)
        XR(K)=XR(K)+DX
         EPABK=EPS*ABS(XR(K))
        IF (ABS(DX).GT.EPABK) GO TO 9
7       CONTINUE
C
        RETURN
        END
C
C END OF RROOT
C
C
C
C
C
C SUBROUTINE STAB
C
        SUBROUTINE STAB (XC,YC,R,XINP,YINP,MINP,MX,MYE,SU,FX,D,DM,YY)
C
C This subroutine searches automatically for the smmalest factor
C of safety starting with the initial data set XC,YC,R
C
C The parameters have the following significance
C Xc,YC  Coord of the center of the arc
C R      Radius of the arc
C XINP   Coord of the points describing the x-section of
C YINP   the embankment
C MINP   No.of XINP/YINP points
C MX     No. of equally spaced points in X-dirn
C MYE    No. of equally spaced points in Y-dirn
C SU     Vector of shear strengths with MX*MYE elements
C FX     Minimum factor of safety
C D      Maximum step size be used in the search program
C DM     Minimum step size be used in the search program
C YY     Minimum permissible value for YC
C X,Y,Z  Auxiliary vectors
C
        DIMENSION XINP(1),YINP(1),SU(1),X(2),Y(2),Z(2)
C
C Evaluate safety factor at initial base point
C
        X(1)=YC
        X(2)=XC
        KEN=-1
11      KEN=KEN+1
        DEL=D
        CALL VARYR (X(1),X(2),R,XINP,YINP,MINP,MX,MYE,SU,FX,DM,YY)
4       FS=FX
        DO 1 I=1,2
        Y(I)=X(I)
1       Z(I)=X(I)
C
C EXPLORATORY MOVES
C
        DO 2 I=1,2
        Y(I)=Z(I)+DEL
        CALL VARYR (Y(1),Y(2),R,XINP,YINP,MINP,MX,MYE,SU,FY,DM,YY)
        IF (FY.LT.FS) GO TO 5
```

```
      Y(I)=Z(I)-DEL
      CALL VARYR (Y(1),Y(2),R,XINP,YINP,MINP,MX,MYE,SU,FY,DM,YY)
      IF (FY.LT.FS) GO TO 5
      Y(I)=Z(I)
      GO TO 2
 5    FS=FY
 2    CONTINUE
      IF (FS.LT.FX) GO TO 6
      IF (DEL.LE.DM) GO TO 10
      DEL=DEL/2.
      GO TO 4
C
C PATTERN MOVE
C
 6    DO 3 I=1,2
      A=Y(I)-X(I)
      IF (A) 7,8,9
 7    A=-2.*DEL
      GO TO 8
 9    A=2.*DEL
 8    B=X(I)
      X(I)=Y(I)
      Y(I)=B+A
 3    CONTINUE
      FX=FS
      CALL VARYR (Y(1),Y(2),R,XINP,YINP,MINP,MX,MYE,SU,FS,DM,YY)
      IF (FS.LT.FX) GO TO 6
      GO TO 4
C
C Start new search if the circle giving the minimum safety factor
C so far does not outcrop at or in front of the embankment toe
C
 10   IF (KEN.EQ.1) GO TO 12
      FMIN=FX
 13   YC=X(1)
      XC=X(2)
      IF (KEN.EQ.1) GO TO 14
      IF ((XC+SQRT(R*R-YC*YC)).LT.XINP(MINP)) GO TO 11
      GO TO 14
 12   IF (FMIN.GT.FX) GO TO 13
      FX=FMIN
 14   RETURN
C
      END
C
C END OF STAB
C
C
C
      SUBROUTINE VARYR (YC,XC,R,XINP,YINP,MINP,MX,MYE,SU,FS,DMIN,YY)
C
C This subroutine evaluates the factors of sefety for NRAD
C trial arcs with the same center XC/YC, but different radii.
C
      DIMENSION XINP(1),YINP(1),SU(1),F(10)
C     DIMENSION C(6)
C
      COMMON/ SAPOD/ IOUTP,W,H,GLOAD,CLOAD,NARC,NRAD
C
C Arcs whose centers lie below YY are not considered
```

```
C
          IF (YC.LT.YY) go to 10
C
C Determine minimum and maximum radi possible
C
        RMIN=YC
        IF (XC.LT.XINP(MINP)) GO TO 1
        AI=XC-XINP(MINP)+DMIN
        RMIN=SQRT(AI*AI+YC*YC)
 1      RMAX=YC+H
        AI=YC-YINP(1)
        AI=SQRT(AI*AI+XC*XC)
        IF (RMAX.GT.AI) RMAX=AI
        IF (RMAX.GE.RMIN) GO TO 2
 10     R=0.
        FS=.1E36
C       FS=1.0E35
        GO TO 3
 2      R=RMAX
C
C Determine the factor of safety for the maximum radius
C
        CALL DETFS (XC,YC,R,XINP,YINP,MINP,MX,MYE,SU,FS)
        IF (RMAX.LE.(1.02*RMIN)) GO TO 3
        NN=NRAD-1
        IF (NN.EQ.0) GO TO 3
        AI=NN
        DELTA=(RMAX-RMIN)/AI

 Determine the factors of safety for arcs with radii
 RR=RMIN+(I-1)*DELTA, and store them in vector F at place 2*1-1

        RR=1.00001*RMIN-DELTA
        DO 4 J=1,NN
        RR=RR+DELTA
        CALL DETFS (XC,YC,RR,XINP,YINP,MINP,MX,MYE,SU,F(J))
 4      CONTINUE

 Search for the minimum factor of safety which is then
 returned to the calling program together with the
 corresponding radius

        DO 5 I=1,NN
        IF (F(I).GE.FS) GO TO 5
        FS=F(I)
        AI=I-1
        R=RMIN+AI*DELTA
 5      CONTINUE

 3      RETURN
        END

 END OF VARYR

 BEGIN SUBROUTINE EFGEN

        SUBROUTINE EFGEN (PSI,T,EIG,IVAR,MM,NN,D,LI)

 This subroutine generates the time-dependent diagonal matrix D
```

```
C PSI     Vector which considers the influence of the soil parameters
C T       Time for which the diagonal matrix D is generated
C EIG     Vector of eigen values
C IVAR=0 Const. soil parameters
C IVAR=1 Variable soil parameters
C MM=     No. of points XT for which D must be evaluated
C NN      No. of eigenvalues
C D       Diagonal matrix to be returned
C
      DIMENSION PSI(1),EIG(1),D(1)
C
C
                 EF=64.
      IF (T.NE.0.) GO TO 7
      LAST=MM*NN
      DO 8 I=1,LAST
 8    D(I)=1.0
      RETURN
 7    IF (IVAR.EQ.0) GO TO 1
C
C VARIABLE SOIL PARAMETERS
C
      II=0
      DO 2 J=1,MM
      PSIT=PSI(J)*T
      DO 2 I=1,NN
      if (MM.EQ.1) PSIT=PSI(I)*T
      II=II+1
         D(II)=10.**((PSIT*EIG(I)/2.302585)/EF)
 2    CONTINUE
      RETURN
C
C CONSTANT SOIL PARAMETERS
C
 1    PSIT=PSI(1)*T
         do 3 I=1,NN
         D(I)=10.**((PSIT*EIG(I)/2.302585)/EF)
        IF (MM.LT.2) GOTO 3
      II=I
      DO 6 J=2,MM
      II=II+NN
 6    D(II)=D(I)
 3    CONTINUE
      RETURN
C
      END
C
C END OF SUBROUTINE EFGEN
```

COVER DESIGN BY ALDO GIORGINI